Integrated Management Plan for Aquatic Weeds
For
The Tahoe Keys Lagoons

2018 Update
January 31, 2018

Integrated Management Plan for Aquatic Weeds
For
The Tahoe Keys Lagoons

Prepared for

Tahoe Keys Property Owners Association
South Lake Tahoe,
California

Prepared by

Sierra Ecosystem Associates

In association with
Dr. Lars Anderson

Acknowledgments

The Integrated Management Plan (IMP) is the result of a collaborative process engaging stakeholders and representatives of federal, state, and local agencies to identify a strategy to control aquatic plants in the waterways of the Tahoe Keys lagoons and was several years in the making. The IMP was developed with direction from and review by a panel of nationally recognized experts in the fields of aquatic plant and animal biology, with input from a technical review group comprised of members of several agencies. A special thank you is extended to these experts, specialists, and interested citizens for their assistance.

Tahoe Keys Property Owners Association Water Quality Committee Members

Andrew Kopania	Susan Chandler	James Jones
Chris Disney	Marla Weitzman	John Larson

Expert Review Panel Members

These members took part in the review of the initial IMP in 2016.

Joe DiTomaso, Ph.D. Panel Chairperson UC Davis Cooperative Extension	Sudeep Chandra, Ph.D. Associate Professor Department of Natural Resources and Environmental Science, University of Nevada, Reno	Kurt Getsinger, Ph.D. US Army Engineer Research and Development Center
Joel Trumbo Senior Environmental Scientist California Department of Fish and Wildlife	Pat Akers, Ph.D. Branch Chief California Department of Food and Agriculture	

Contributors

Lars Anderson, Ph.D.
Waterweed Solutions
Author

Rick Lind,
President, Sierra Ecosystem Associates

The Current Staff of Sierra Ecosystem Associates:

Jeremy Waites
Author, GIS Specialist

Rayann LaFrance,
Document Production

Krystle Heaney,
Editor, Author, GIS Support

Kristen Hunter
Author

Prior Staff Contributors:

Kris Kiehne
Editor, Author

Melissa Marquez,
Author

Chad Johnson
Author

Tahoe Keys Property Owners Association
Integrated Management Plan for Aquatic Weeds
Table of Contents

List of Figures

List of Tables

Appendices

EXECUTIVE SUMMARY

The Tahoe Keys in the City of South Lake Tahoe, California is a multi-use development with homes and townhomes, the largest public marina in Lake Tahoe, and a commercial center. The surface waters of the Tahoe Keys development are also known collectively as the Tahoe Keys lagoons. These waters provide multiple recreational opportunities for residents and visitors.

Aquatic plants are important in aquatic systems and provide food, habitat, and shelter for fish and other aquatic organisms. However, non-native and certain native aquatic plants can become widely established, outcompete native plants for space and nutrients, and reach nuisance status. This situation reduces beneficial uses, damages the natural ecosystem, and poses safety hazards such as entanglement to boats or formation of a dense canopy cover of aquatic plants that decreases water quality. Populations of two invasive, non-native aquatic plants have been observed in marinas and other recreational areas in Lake Tahoe, the first appearing in the 1960s (Eurasian watermilfoil) and the second that was initially observed in 2003 (curlyleaf pondweed).

Since the 1980's the Tahoe Keys Property Owners Association (TKPOA) has taken responsibility for removing aquatic plants from the Tahoe Keys lagoons. Despite these on-going efforts, the presence of aquatic invasive plants, both native and non-native, in the Tahoe Keys lagoons has reached nuisance levels. Recent aquatic plant surveys show nearly 100 percent aquatic plant canopy coverage in many areas of the Tahoe Keys lagoons. The non-native species, Eurasian watermilfoil and curlyleaf pondweed, are the primary component of this infestation. The volume of weeds removed from the Tahoe Keys lagoons is approximately 10,000 or more cubic yards annually. Reported cost for operation in the Tahoe Keys of roughly 145 acres during 2016 equates to approximately $2,900 per acre, including operation, labor, and disposal.

In addition to the economic impact, weed removal is costly in terms of environmental impacts: fossil-fueled machines are used to remove the weeds from the waterways and to remove the weed fragments from the Tahoe Basin, and weed removal can result in fish mortality and disturbance to other native aquatic species habitat.

In addition to the local impacts of invasive plants, many species of aquatic plants can reproduce from fragments and colonize in new areas. Fragments can be self-generated from aquatic plants, or during the mechanical harvesting process, or when broken off by

boat keels and propellers, and by wind and strong currents. These weed fragments can be transported away from the site of origin where the new population can become established. The continued spread of curlyleaf pondweed in Lake Tahoe underscores the threat from these fragments and other reproductive structures.

The TKPOA Water Quality Committee (WQC) has developed this *Integrated Management Plan for Aquatic Weeds for the Tahoe Keys Lagoons* (IMP) to address the escalating problems of uncontrolled aquatic weed growth. The IMP applies an integrated pest management approach to aquatic weed control by combining sound ecological principles with proven methods for aquatic plant control. For this IMP, control methods are limited to those that are suitable to and qualify for current regulatory direction and authorization for the site conditions of the Tahoe Keys lagoons.

History of Aquatic Weed Control Work in the Tahoe Keys

From the 1960s until the 1980s, the lagoons and waterways were largely clear and free of invasive weeds. Since the 1980s and the establishment of the weeds, TKPOA has relied primarily on mechanical harvesters to remove aquatic plants; however TKPOA has also used other control methods in the past. A circulation system known as the Solar Bee© was installed in the independent, separately owned Marina Lagoon. The system did not reduce the growth of aquatic weeds and in fact masses of plants thrived around the Solar Bee systems. TKPOA also collaborated with the Tahoe Resource Conservation District (TRCD) and Tahoe Regional Planning Agency (TRPA) in a demonstration project using bottom barriers that physically block light from aquatic vegetation. The result of this project was that the barriers prevented the growth of aquatic weeds underneath them, but weeds grew in the accumulated sediment on top of the barrier and returned after removing the barriers.

History of the IMP Development

The WQC began developing an integrated management plan in 2013 and worked with aquatic plant expert Lars Anderson, Ph.D., to identify suitable control methods for the Tahoe Keys lagoons. The WQC also reviewed aquatic plant control methods and several of the many integrated management plans for aquatic plants that have been developed throughout the United States, including for Big Bear Lake and Clear Lake in California, Lake Stevens in Washington, Chetek Lakes and Balsam Lake in Wisconsin. Based on this initial information gathering, the WQC developed an annotated outline of

their plans for an integrated management plan for the Tahoe Keys lagoons.

In 2014, the Lahontan Board issued Waste Discharge Requirements (WDRs) to TKPOA. This document specified, in part, that an integrated management plan for aquatic plants be developed. In response to the WDRs, the WQC expanded on the annotated outline from 2013. The WQC solicited advice from experts in the field of aquatic biology, and from a range of resource agencies in the Lake Tahoe Basin and other concerned citizens groups and associations. This culminated in the Draft Integrated Weed Management Plan (IWMP) that was released to the public in August 2015.

In December 2015, the Lahontan Regional Water Quality Control Board (Lahontan Board) issued comments on the Draft IWMP to TKPOA. The Lahontan Board acknowledged that the IWMP covered many of the elements stipulated by the WDRs, but stated that additional evaluation of impacts and efficacy of the various control methods being proposed was needed prior to including them in or excluding them from the IWMP. Of particular concern was the proposed use of aquatic herbicides.

The WQC revised the Draft IWMP to develop the IMP for Aquatic Plants, which was submitted to the Lahontan Board in May 2016. Compared to the IWMP, the May 2016 IMP restricted the scope of proposed control methods to those authorized by the WDRs. The May 2016 IMP was also more specific in describing targets for control and criteria to determine success in meeting the goals and objectives.

The May 2016 IMP proposed an extensive research and testing program to evaluate suitability of a range of new methods of aquatic plant control. This included researching additional mechanical methods, such as rotovating, innovative methods, such as UV light, and evaluating aquatic herbicides and applying for the necessary permits from the Lahontan Board, the State of California, and the TRPA for a limited test project.

On August 18, 2016, the Lahontan Board responded to TKPOA that in order to obtain approval for the IMP, discussion of aquatic herbicides must be relocated to an appendix of the document and must not appear in the main text. Therefore, a new Appendix A has been added to this document, which provides the information about aquatic herbicides which previously appeared in the main text of the IMP. A copy of the letter from the Lahontan Board is in Appendix B.

TKPOA has been open with the public about its deliberations regarding the use of aquatic herbicides. To avoid even the appearance of duplicity, it is essential to direct attention to Appendix A for both the new readers of this IMP and those who have been engaged from the start in the process of drafting the IMP. Placement of this information in an appendix should not in any way be construed as an indication that the efficacy, utility and proven safety and utility of these products is in question. Their eventual approval and inclusion in a future update to the IMP may prove essential to meeting the stated goals of the IMP and to protect Lake Tahoe from the continuing threat from invasive aquatic weeds.

Scope of Work

In this IMP, the range of control methods allowed by the WDRs are described as well as how each can be used most effectively in the Tahoe Keys lagoons. The IMP also describes a program of research and on-site testing additional aquatic plant control methods, some in combination and some of which are new or novel. Some of the methods in the research program will require additional regulatory review, but these methods have been used safely and successfully in waters of California and in the US. New methods that have demonstrated efficacy and suitability for use in the Tahoe Keys lagoons will be considered for future updates to the IMP.

The geographical scope of the IMP covers the areas under the management control of TKPOA where aquatic weed removal work takes place. In general, these areas are the West Channel, the Main Lagoon, and the many smaller lagoons connecting to the Main Lagoon, Lake Tallac, the East Channel, and portions of the Marina Lagoon. Other property owners and managers are responsible for aquatic weed removal in areas over which they have control.

The three species that are the initial focus of the IMP activities are the introduced species Eurasian watermilfoil and curlyleaf pondweed and the native species, coontail. Current studies consistently show that these three plants are the predominant species present in the Tahoe Keys lagoons and that canopy coverage can be nearly 100% in some areas of the lagoons.

Goals and Objectives of the IMP

The 2014 WDRs issued to TKPOA stated five objectives that the IMP was to accomplish; therefore, the first Goal of the IMP is to fulfill the objectives named in the WDRs.

These objectives are:

- Eliminate spreading of aquatic invasive species (AIS) from the Tahoe Keys to greater Lake Tahoe
- Enhance the overall water quality of the Tahoe Keys lagoons and Keys Marina thereby improving Lake Tahoe water quality and associated clarity
- Reduce habitat for non-native fish and enhance habitat for native fish in the Tahoe Keys lagoons and Keys Marina
- Restore and maintain established beneficial recreational uses, including water contact safety in the Keys lagoons and commercial uses in the Keys Marina
- Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants

The WQC drafted a second goal to support improvements and updates to the IMP. This goal states that TKPOA will continue to refine existing methods of aquatic plant control and to research new, safe, cost-effective methods to control aquatic invasive plants. The Adaptive Management Program Committee (described in Section 4.3 of this IMP) and the Lahontan Board will use established, objective criteria to evaluate these methods and propose effective, feasible methods for inclusion in updates to the IMP.

Objectives for this second goal are:

- Identify and confirm safety and success of new and novel aquatic invasive plant control methods by reviewing scientific literature and reports of these methods used under similar settings and operational conditions.
- Conduct and evaluate small-scale demonstrations of localized control methods in defined areas of the Tahoe Keys lagoons. These small-scale demonstrations may include methods not specified as control measures in the WDRs but will be conducted under the appropriate authorization of and permits issued by the Lahontan Board.

Aquatic plant control options available for the Tahoe Keys lagoons are constrained by existing regulatory direction and concerns regarding the proximity of the Tahoe Keys lagoons to Lake Tahoe, a designated Outstanding National Resource Water.

2018 IMP: Summary

The 2014 WDRs issued to TKPOA recognize and authorize the following methods of aquatic weed control for the Tahoe Keys lagoons:

- The use of mechanical harvesting
- Hand-pulling of aquatic weeds
- Placement of up to 5 acres of bottom barriers
- Education and Outreach to the members of TKPOA and staff

The 2014 WDRs do not authorize chemical or any additional control methods for aquatic plants.

Each of the four named control methods has benefits and constraints in their application to the site-specific conditions of the Tahoe Keys lagoons. Mechanical harvesting gives immediate, but temporary relief in the waterways. Hand pulling is relatively easily, but is limited to small areas and shallow waters where plants can be safely accessed, or to where scuba divers can be used. Bottom barriers are effective while in place, but are dislodged by wave action if not anchored securely. Their use (limited to five acres) represents approximately 3% of the 172 acres of the lagoons. Education and outreach to the members of TKPOA and the residents of the development will include aquatic weed identification and measures to prevent proliferation of aquatic weed populations, but these measures do not provide immediate relief from aquatic plant infestations.

Implementation of the IMP

In the 2018 implementation of the IMP, TKPOA will integrate the approved control methods listed above and will refine their use. In addition, combinations of non-herbicide control methods will be evaluated. Mechanical harvesting will be directed more efficiently by using GPS reporting of infestations to schedule treatment. New skimmers and collection boats will be implemented to more effectively recover fragments in the Keys Lagoons. TKPOA will also seek funding to implement an integrated non-herbicide, combination methods test that will take place over the course of several years.
The Education and Outreach Program provides single-family property owners and residents many opportunities to learn about aquatic weeds, water quality, and actions they can take to help stop the proliferation of aquatic weeds in the Tahoe Keys lagoons and Lake Tahoe.

Evaluation of IMP Activities

The results of the control activities and the research and testing program will be considered in the Adaptive Management Review Program for the IMP. This annual review process is essential for continued improvement of the IMP and achievement of long-term

control of aquatic weeds in the Tahoe Keys lagoons and for successful implementation of an adaptive management strategy.

The WQC has established five success criteria to evaluate the IMP activities:

- Reducing the volume of target plants by 90% from 2016 levels
- Maintaining sufficient Vessel Hull Clearance (VHC) (distance between top of plant canopy and bottom of the vessel)
- Increasing the diversity and presence of native aquatic plant species in the Tahoe Keys lagoons
- Reducing the production of fragments from aquatic weed control activities
- Minimizing effects on animals and non-target plants

Conclusion

The results of the planned 2018 activities and proposed 2019 evaluations will provide necessary information for TKPOA to improve the IMP. Continued public input, collaboration with stakeholders, consultations with resource and regulatory agencies, and consideration of scientific developments are also necessary to develop a long-term solution for the Tahoe Keys lagoons and the protection of Lake Tahoe as an Outstanding National Resource Water.

This Plan is continually evolving and is the result of a collaborative process engaging stakeholders and representatives of federal, state, and local agencies to identify a strategy to control aquatic plants in the waterways of the Tahoe Keys lagoons. The initial Plan in 2015 was developed with input from a panel of nationally recognized experts in the fields of aquatic plant and animal biology, from a technical review group comprised of members of several agencies and organizations in California and Nevada, and with contributions from residents of the Tahoe Keys and the general public.

1.0 BACKGROUND AND NATURAL SETTING

Tahoe Keys and Lake Tahoe - Copyright 2006 Regents of the University of California. Photo used by permission

Aquatic invasive weed control is a specialized field of pest management that relies on technical and operational expertise. The Integrated Management Plan for Aquatic Weeds for the Tahoe Keys Lagoons (IMP) describes an approach to control aquatic invasive weeds that uses carefully selected control methods that match site-specific conditions and which are used by knowledgeable technicians in order to achieve the desired results. Success of the control activities relies on technical support to objectively evaluate conditions prior to and after treatment. Global Positioning System (GPS) technology will continue to be used to locate infestations of aquatic weeds and to direct control operations to the proper locations. Monitoring with hydroacoustic sampling precisely describes the size of the infestation to help determine if the control activity has met established success criteria.

The IMP also specifies an annual review that is both an adaptive and additive process. This will allow the Tahoe Keys Property Owners Association (TKPOA) to respond to changed conditions in the Tahoe Keys lagoons. Modifying aquatic weed control activities and researching and testing new methods and combinations of aquatic weed control will assist in determining the suitability of control methods and whether new methods can be added to the suite of control options available.

1.1 History of the IMP Development

Through collaborations with resource and regulatory agencies, TKPOA Water Quality Committee (WQC) began designing an integrated management plan in 2013 and worked with aquatic plant expert Lars Anderson, Ph.D., to identify suitable aquatic plant control methods for the Tahoe Keys lagoons. The WQC also reviewed control methods and several of the many integrated management plans for aquatic plants that have been developed throughout the United States, including for Big Bear Lake and Clear Lake in California, Lake Stevens in Washington, and Chetek Lakes and Balsam Lake in Wisconsin. Based on this initial information gathering, the WQC developed an annotated outline of their plans for an integrated management plan for the Tahoe Keys lagoons.

In 2014, the Lahontan Regional Water Quality Control Board or Lahontan Board (Lahontan Board) issued the Waste Discharge Requirements (WDRs) to TKPOA. This document specified, in part, that an integrated management plan for aquatic plants be developed. In response to the WDRs, the WQC expanded on the annotated

outline from 2013. The WQC solicited advice from experts in the field of aquatic biology, and from a range of resource agencies in the Lake Tahoe Basin and other concerned citizens groups and associations. This culminated in the Draft Integrated Weed Management Plan (IWMP) that was released to the public in August 2015. The public provided many comments on the Draft IWMP. Some commenters were supportive of the Draft IWMP. Other commenters provided helpful information on alternative methods. Some commenters were opposed to the IWMP.

In December 2015, the Lahontan Board issued comments on the Draft IWMP to TKPOA. The Lahontan Board acknowledged that the IWMP covered many of the elements required by the WDRs, but stated that additional evaluation of impacts and efficacy of the various control methods being proposed was needed prior to including or excluding them from the IWMP.

The WQC used the comments received as the basis for the IMP submitted to the Lahontan Board in May 2016. Compared to the IWMP, the IMP was more restricted in the scope of proposed control methods, more specific in describing targets for control and criteria to determine success in meeting the goals and objectives. The May 2016 IMP also described in detail a program to research a range of new methods of aquatic control, including researching and applying for permits for a limited test project using aquatic herbicides.

On August 18, 2016, the Lahontan Board responded to TKPOA and stipulated the following:

> "By October 1, 2016, submit a revised IMP where all text regarding use of aquatic herbicides has been removed from the body of the IMP. It is acceptable to place text about aquatic herbicides into an appendix to the IMP."

Before receiving the August 18th letter, TKPOA had held several meetings discussing the requirements for obtaining all necessary approvals and permits for the limited test project using aquatic herbicides. TKPOA had also undertaken an extensive education and outreach program to engage water purveyors in the Tahoe Basin, the Sierra Club, the League to Save Lake Tahoe, and the Tahoe Regional Planning Agency (TRPA) to address concerns about a limited aquatic herbicide test project.

On September 26, 2016, the Tahoe Daily Tribune, a paper of general circulation in the City of South Lake Tahoe and the Tahoe area,

reported on TKPOA's efforts to pursue permitting for an aquatic herbicide test in the Tahoe Keys lagoons (Tribune 2016).

Because TKPOA has previously engaged the public about their intent to acquire the permits for a limited test project using aquatic herbicides, it is imperative to inform the reader that discussion of aquatic herbicides has been relegated to Appendix A as a condition of approval of the 2016 IMP by the Lahontan Board. TKPOA has been and continues to be committed to open and transparent communication with the public about the IMP.

A copy of the August 18, 2016 letter from the Lahontan Board to TKPOA can be found in Appendix B.

1.2 Location and Area Description

Lake Tahoe is a unique alpine lake on the California-Nevada border. The Lake is known worldwide for its outstanding blue waters and was designated an Outstanding National Resource Water by the State of California and the US EPA in 1980. The Lake offers many recreational opportunities and is enjoyed year round for its scenic beauty.

The Tahoe Keys is a multi-use development situated at the southern end of Lake Tahoe on approximately 372 acres of land. The development features 1,529 homes and townhomes, marinas, and a commercial center. There are three primary man-made water features in the Tahoe Keys facility: the Main Lagoon, the Marina Lagoon (which includes the independently owned Keys Marina and Yacht Club), and Lake Tallac. These three water features are considered the Tahoe Keys lagoons, referred to throughout this document (Figure 1).

The surface area of the water of the Tahoe Keys lagoons is approximately 172 acres in size, or 0.3 square mile, representing a very small percentage of the surface area of Lake Tahoe, which is approximately 192 square miles. The Tahoe Keys lagoons have two narrow, direct connections to Lake Tahoe: the West Channel connects the Main Lagoon and the East Channel connects the Marina Lagoon. These channels provide the only direct boat access to Lake Tahoe from the Tahoe Keys lagoons. Lake Tallac can connect to the Main Lagoon at a diversion structure between the two water bodies. Discharges to the Main Lagoon from Lake Tallac occur infrequently. Lake Tallac also has an intermittent connection to Lake Tahoe via Pope Marsh during high water events.

Figure 1. Overview Map of Keys Lagoons and Lake Tallac

The Tahoe Keys lagoons differ from Lake Tahoe in several ways. The Tahoe Keys lagoons have shallow waters, approximately 20 to 30 feet at maximum depth with an average depth of about 12 feet. Lake Tahoe is 1,645 feet at the deepest point with an average depth of 1,000 feet. The waters of the Tahoe Keys lagoons are typically warmer than the water of Lake Tahoe during the spring and summer months, but can be cooler during the fall and winter months. Typically, much of the Tahoe Keys lagoons are frozen for several months in the winter, whereas Lake Tahoe never freezes. However, the shallow shorelines have some accumulated ice cover. The waters of the Tahoe Keys lagoons are typically more turbid than the clear waters for which Lake Tahoe is famous. Lastly, the bottom layer of the Tahoe Keys lagoons is composed of fine sediments, a remnant of the past when the area was a marsh, as opposed to the coarse, decomposed granite typically found at the bottom of Lake Tahoe. The bottom of the Tahoe Keys lagoons also has an accumulation of organic matter from decades of aquatic plant growth, senescence, and decay.

The Tahoe Keys development has six landowners or types of landowners:

- Private homeowners who are members of
- TKPOA
- The non-profit TKPOA owns common areas

- The Tahoe Keys Beach and Harbor Association
- The Tahoe Keys Marina and Yacht Club
- TKV Properties Holdings LLC, which owns commercial property known as Tahoe Keys Village
- The State of California, which owns land to the east and southeast of the Tahoe Keys development under the auspices of the California Tahoe Conservancy (CTC), one of 10 conservancies in the State of California

The Tahoe Keys development includes beaches, swimming pools, tennis courts, basketball courts, pedestrian pier to Lake Tahoe, boat docks, and park areas. Ancillary facilities of the development include water wells and a potable water distribution system, a water treatment facility, and lagoon water circulation system.

The Tahoe Keys lagoons provide boating access to Lake Tahoe via the East Channel in the Marina Lagoon and via the West Channel in the Main Lagoon. The Tahoe Keys lagoons are used by commercial interests and by the residents and visitors to the area for recreational boating, both by power boating and non-motorized boating and for recreational fishing. The aesthetic values of the Tahoe Keys lagoons include the waterways and views of the surrounding mountains and Lake Tahoe, which are key attractions for residents and visitors alike.

The Main Lagoon of the Tahoe Keys contains the majority of private residences in the overall development and has many interconnected waterways and coves. The individual private property owners who belong to TKPOA own the majority of the Main Lagoon. TKPOA itself also has an ownership interest in the Main Lagoon.

The Marina Lagoon contains residences, commercial operations, governmental operations, and commercial space. This includes the location of the Tahoe Keys Marina, a privately owned and operated boat launching facility, which is the largest full-service marina at Lake Tahoe. The Tahoe Keys Marina provides boat services, fueling, mooring, boat storage, and launching services to the general public, Tahoe Keys property owners and renters, boat rental and charter and other recreational companies, marine construction companies, law enforcement, and agencies and universities for research activities on Lake Tahoe.

The Marina Lagoon area is owned by:

- The Tahoe Keys Marina and Yacht Club
- TKPOA, which holds in common individual docks used by owners of townhomes in the Tahoe Keys development

- The Tahoe Keys Beach and Harbor Association (TKB&HA) which maintains 266 boat slips for its members
- The California Tahoe Conservancy, which owns the area known as the Turning Basin at the northeast edge of the Marina Lagoon

TKV Properties Holdings LLC owns the commercial center at the Marina Lagoon known as Tahoe Keys Village. This parcel is adjacent to the Marina Lagoon.

Lake Tallac is located at the southern edge of the Tahoe Keys development and was purchased by TKPOA from Lagoon Associates, Inc. in 2016.

The federal government controls the waters of Lake Tahoe and the US Forest Service (USFS) controls areas to the south and to the west of the Tahoe Keys development.

TKPOA is responsible for maintaining the common areas of the Tahoe Keys development and maintains navigation in the waterways of the Tahoe Keys lagoons.

Ownership interests are summarized in Table 1 and Figure 2.

Table 1. Summary Table - Tahoe Keys Water Features and Ownership

Water Feature	Surface Area (Acres)*	Property Ownership	Connection to Lake Tahoe
Main Lagoon	110	• 700 Private Property Owners • TKPOA	West Channel
Marina Lagoon	32	• Tahoe Keys Marina and Yacht Club • TKPOA (Individuals) • TKPOA (Docks held in common for owners of townhomes) • Tahoe Keys Beach and Harbor Association • CTC	East Channel
Lake Tallac	30	• TKPOA	Pope Marsh

Source: Lahontan Regional Water Quality Control Board
**Acreage given is approximate maximum surface area.*

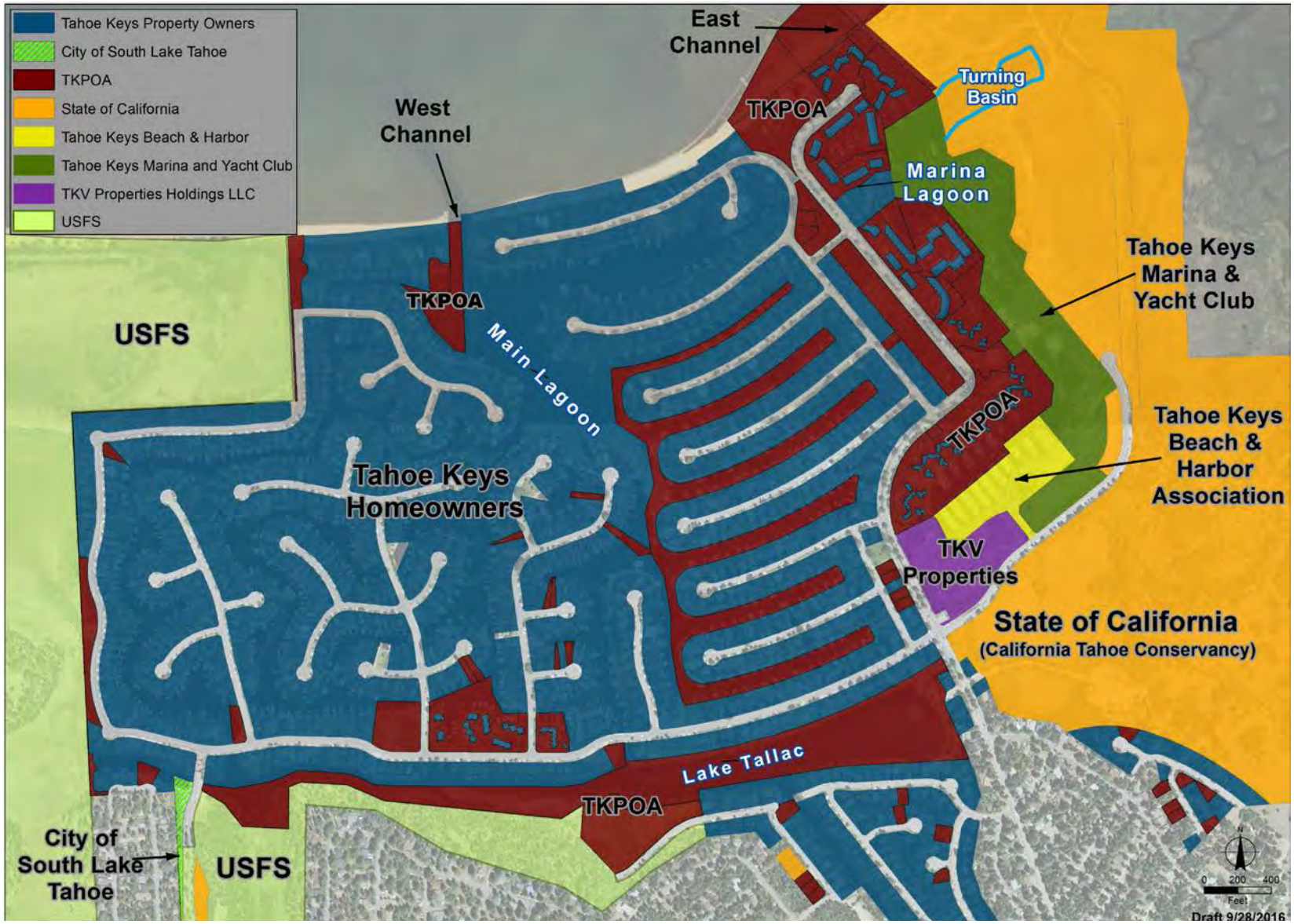


Figure 2. Property Ownership Map
(Source: TKPOA)

1.3 Hydrology of the Tahoe Keys

The Tahoe Keys and Keys Marina were constructed in the 1960s on the Upper Truckee River Marsh by excavating the lagoons and capping the soil with sand to form stable building bases. In conjunction with construction of the Tahoe Keys, the Upper Truckee River was diverted to a channel on the east side of the Keys Marina Lagoon (USGS 2000).

The three water bodies of the Tahoe Keys lagoons each have a connection to Lake Tahoe. The Main Lagoon has smaller lagoons and coves with residential docks and is connected to Lake Tahoe by the West Channel. The Keys Marina Lagoon connects to Lake Tahoe via the East Channel. Lake Tallac normally discharges into Pope Marsh but also can drain into the Main Lagoon during flood conditions via gates in the diversion structure located under Venice Drive.

Figure 3. Aquatic Features Surrounding the Tahoe Keys

The Tahoe Keys watershed is approximately 372 acres or 0.6 square mile, as compared to the much larger watershed of Lake Tahoe at 501 square miles. There are 63 inlet streams to Lake Tahoe, but no natural surface water channel discharges into the Tahoe Keys lagoons. Lake Tallac intercepts most upland storm water runoff that flows towards the Tahoe Keys and this water body in turn discharges

to Pope Marsh. With this barrier to the south and the Upper Truckee River to the east, only a negligible amount of storm water runoff reaches the Tahoe Keys from lands that are not part of the Tahoe Keys development. The majority of the watershed that discharges surface flows into the Tahoe Keys lagoons is developed residential property. Most of the surface flows are directed to a storm drain system owned and operated by the City of South Lake Tahoe under a Municipal Separate Storm Sewer System Permit.

1.4 Seasonal Patterns of Water Movement

The Tahoe Keys lagoons experience seasonal inflow and outflow of water to and from Lake Tahoe. Since the contributing watershed to the Tahoe Keys lagoons is small compared to that of the Lake, during periods of stormwater runoff and snowmelt, the water surface level in the Lake rises faster, causing water to flow into the lagoons from the Lake during early spring to early summer. Conversely, as streamflow into the Lake diminishes, the Lake level begins to lower and water from the Tahoe Keys lagoons flows out into the Lake during the summer through fall. In addition to this seasonal pattern, some mixing of waters between the Main Lagoon/Marina Lagoon and the Lake may occur from thermal gradients and wind effects through the West and East interconnecting channels.

The Tahoe Keys lagoons are directly connected to Lake Tahoe at the West and East channels. Under typical conditions, the rate of water flow out of the Keys slows as the season progresses from late summer (August to September) to fall (September to October). Dr. Lars Anderson completed a detailed assessment of water movement from specific sites within the Main Lagoon in 2011 (Anderson 2011a). The tracking dye, Rhodamine WT, was used as a surrogate to simulate herbicide movement, dissipation and residence time. Residence time is also referred to as flushing time and refers to the average time water, or a dissolved substance in water, is contained in a lake or reservoir. The study showed that narrow coves, or dead-end sites, had long residence times, greater than 30 days, regardless of the season. These dead-end sites experienced rapid diurnal mixing of the water as cooler, denser surface water sank overnight. In contrast, open water sites had shorter residence times than the dead-end coves. During the summer, residence times in open water sites lasted hours and in the fall, the residence times were in the range of weeks (Figure 4).

Additional Rhodamine WT dye studies were completed in summer 2016. These studies demonstrated that dye placed near the West Channel in early June moved toward the south and that dye placed

at the same location in late June moved toward the West Channel. The 2016 Rhodamine WT Dye Study also tested a double curtain barrier at two locations in southern lagoons. These curtains prevented the movement of 98% of the Rhodamine WT dye from the site of application during the two-week test period (Anderson 2016).

The mean net annual evaporation from Lake Tahoe has been estimated in the range of 21 inches (DRI 2011) to 51 inches (TERC 2015). Lake levels are also influenced by the release of water at the Truckee River dam in Tahoe City, which augments flows into the Lower Truckee River.

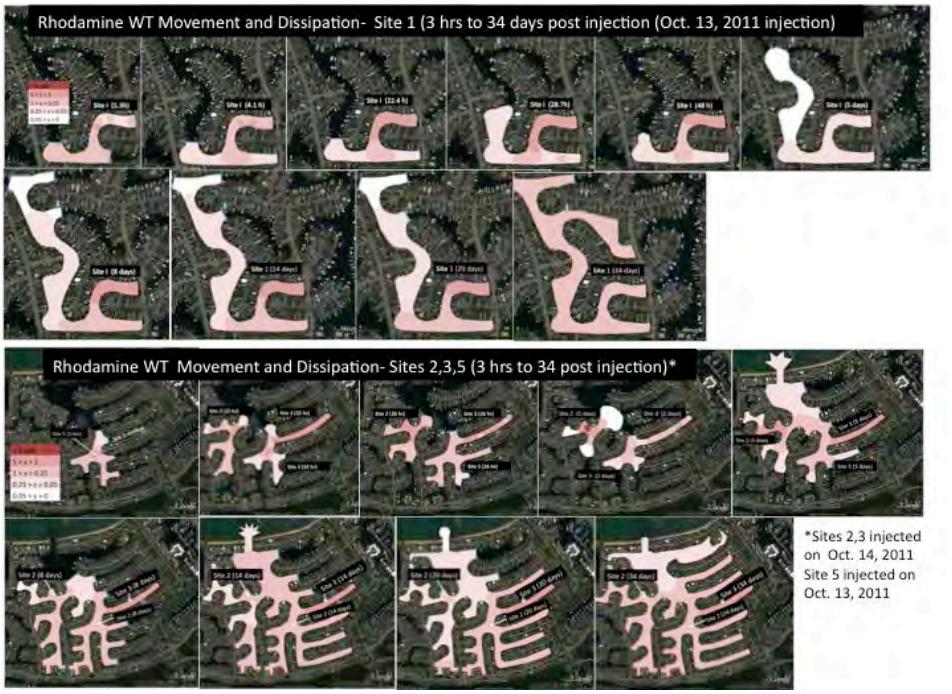


Figure 4. Rhodamine Dye Study Results

Water exchange patterns between the Tahoe Keys lagoons and Lake Tahoe, via the East and West channels, has also been studied by researchers from UC Davis. One study investigated water temperature differences and determined that thermal stratification and the resultant density differences of water were strongly linked to exchange flows during most months of the year, as compared to other influences, such as wind currents. This study estimated residence times of the open water areas of the Main Lagoon channel to be between 2 to 3 days, and residence times in the Marina Lagoon channel to be between 5 and 6 days during most months of the year (La Plante 2008).

As part of a study, modeling potential microbial contamination of the recreational waters of Lake Tahoe, a simulated release of 24,000 neutrally buoyant particles from outside the Tahoe Keys lagoons was

studied (Schladow 2014). The modeling results determined that such particles had the potential to reach the near shore areas southeast and southwest of the Tahoe Keys lagoons within 24 hours. The study also determined that after 24 hours, the majority of the particles would be found above 5 meters in depth, with some particles reaching 10 to 12 meters in depth. The modeling results were also used to simulate the release of herbicide from a point outside the Tahoe Keys lagoons to determine if such a release would reach potable water intakes located to the east and north, which were assumed to be at 15 meters in depth for purposes of the modeling exercise.

The simulated release did not take into account factors known to affect the environmental fate of herbicide molecules. Future studies can evaluate processes such as photolysis and microbial degradation, hydrolysis, adsorption and dilution to more accurately predict movement of particles in and around the waters of Lake Tahoe.

1.5 Biological Communities of Lake Tahoe and Tahoe Keys Lagoons

The Aquatic Ecosystem of the Tahoe Basin

The Tahoe Basin contains a complex ecosystem with both stream and lake aquatic environments that support native and introduced species of fish, benthic invertebrates, birds, and plants.

Lake Tahoe's aquatic ecosystem has changed over time and the current aquatic flora and fauna assemblage is largely the result of human influence. In the 1800's, the lake's aquatic animal communities were relatively simple, with 12 orders of zoobenthic taxa, six zooplankton species, and eight fish taxa (Miller 1951, Frantz and Cordone 1970, Vander Zanden et al. 2003, and Chandra 2009). Over the last 130 years, through a series of species introductions, landscape disturbances such as deforestation, road building and other development, the biological assemblage and the diversity of aquatic species of the region has been dramatically altered resulting in what we see today. The aquatic animal communities of Lake Tahoe now consist of six zoobenthic taxa, five zooplankton species, and 14 fish taxa (Figure 5; TERC 2014).

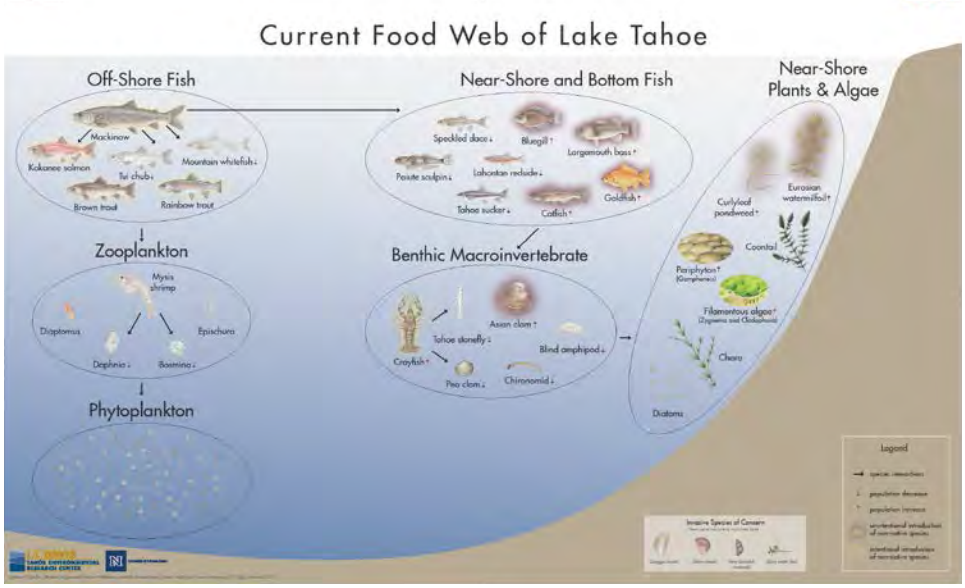


Figure 5. Current Food Web of Lake Tahoe
(Source: TERC, UNR)

Populations of native fish that were once abundant in the region have decreased by perhaps as much as ten-fold since the 1960s (Thiede 1997) or, as in the case of the Lahontan cutthroat trout, have been extirpated. Non-native fish such as largemouth bass and bluegill have become more common. The decline in native populations could be attributed to several causes such as increased water temperature and habitat degradation, caused in part by increased spread of invasive plants, which could modify conditions to promote warm-water non-native fish (Chandra 2009).

Fish of Lake Tahoe and the Tahoe Keys Lagoons

Warm-Water Fish

Several non-native warm-water fish have been introduced to the Tahoe Basin for the purposes of sport fishing and other fish species have been introduced most likely through disposal of aquarium species into the waters. These non-native fish species include largemouth and smallmouth bass, bluegill, black crappie, brown bullhead catfish, golden shiner, common carp and goldfish. Baseline information on the composition of warm-water fisheries in the Lake Tahoe basin, including the Tahoe Keys lagoons, was collected by UNR and CDFW from 2011-2014 as part of the three-year Aquatic Plant Management Research Project (Ngai 2014) and by UNR and the NDSL from 2006-2008 (Chandra 2009). Largemouth bass, bluegill and brown bullhead were the most prevalent species captured in the UNR-CDFW study. The UNR-CDFW study did not find a significant difference in spatial distribution of warm-water

fishes in various locations in the Tahoe Keys lagoons but did determine that the distribution was extensive.

Cold-Water Fish

Native and non-native cold-water fish in the Tahoe Basin include Mountain whitefish, Tahoe sucker, Lahontan sucker, speckled dace, redside shiner, Lahontan Tui chub, Paiute sculpin, Kokanee salmon, brown trout, rainbow trout, and mackinaw. In the UNR-CDFW and UNR-NDSL studies, the following native and cold-water fish were captured in the Tahoe Keys lagoons: Mountain whitefish, Lahontan redside, Lahontan speckled dace, Tahoe sucker, brown trout, rainbow trout and Lahontan Tui chub. Tahoe sucker was the most prevalent species captured in the UNR-CDFW study. Overall, the abundance of native and cold-water fish remains relatively low in the Tahoe Keys lagoons mainly due to the warm-water environment.

Benthic Biota

The most comprehensive information available on Lake Tahoe's benthic biota comes from a study that was completed by Frantz and Cordone in 1963 (USDA 2000). The signal crayfish (*Pacifastacus leniusculus*) is perhaps the most visible and best-known species in the benthic invertebrate community in Lake Tahoe. Even though several fish species, birds, and various mammals, including humans, prey upon crayfish the population appears stable.

There are several endemic deep-water benthic macroinvertebrates (BMI) including the Lake Tahoe benthic stonefly, associated with deep-water communities of plants, algae, mosses and liverworts, and two species of blind amphipods, the Lake Tahoe Amphipod and Lake Tahoe Stygobromid. None of these benthic species is listed as threatened or endangered nor are they listed as USFS Species of Special Concern but they are important indicator species for the ecology of Lake Tahoe.

Avian Species

Common merganser (*Mergus merganser*)

This resident species can be readily identified by its long, slender, bright red bill and short crest at the back of the head. Adult males have a glossy green head and neck and black upper back while females have a reddish brown head and neck but throat is white. This bird bears horny "teeth" and a hooked tip, useful for catching the various kinds of fishes taken for food. Mergansers dive and swim

readily under the surface when searching for prey. Groups of females and young are frequently observed along rivers or secluded lakeshores; they are always nervous and swim quickly away from humans (Zeiner 1988).

Mallard (*Anas platyrhynchos*)

Another resident species of Lake Tahoe, the male mallard is easy to spot with his glossy green head, narrow white collar and tail with up-curled feathers. The female of the species is mottled brown, lighter below with feathers pale-edged. This type of duck typically prefers shallow water such as creeks, ponds, and marshes. They are surface feeders, tipping “bottom up” to reach food plants under shallow water. They are common on quiet waters on almost any lake or smooth stream, particularly those margined with aquatic plants (USDA 2015; Storer 2004).

Canada goose (*Branta canadensis*)

This is the most common goose in North America. It has a black head and neck with a distinctive white "chinstrap" stretching from ear to ear. It is a locally common resident, especially at lakes and parks around human activity. They are often seen swimming on large lakes or streams or feeding on short grasses in lush meadows. Elevated nesting platforms were installed in the Pope Marsh area in 1976 to improve local nesting success of the Canada goose. These long-necked, noisy birds are very abundant during the summer and are readily viewed by visitors (USDA 2015; Zeiner 1988).

California gull (*Larus californicus*)

The California gull is often spotted at Lake Tahoe beaches and is the same gull seen on Pacific Ocean beaches. Adults have a white head, neck, tail and undersurface, and a pale gray back with black wing tips. Adults often visit Lake Tahoe. Typical of most gulls, the California gull is a true scavenger and feeds on garbage, insects, plant material, and fish (Zeiner 1988).

Ring-billed gull (*Larus delawarensis*)

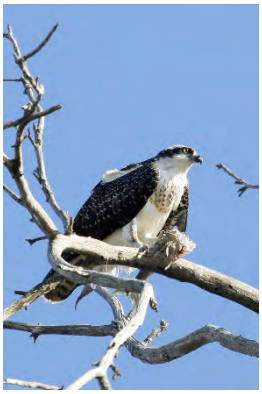
The Ring-billed gull is smaller than the California gull. It has a black stripe around its bill and paler gray back. Although not as common as the California gull, it too, is often seen at Tahoe beaches.

Cliff swallow (*Petrochelidon pyrrhonota*)

These highly colonial swallows commonly nest in the spaces under building eaves or bridges near the water margin. Cliff swallows have a bright forehead and are dark bluish-brown except for an orange rump and creamy white forehead, light gray under and dusky red on sides of face (Zeiner 1988).

Osprey (*Pandion haliaetus*)

Also known as the “Fish Hawk”, the osprey has a characteristic crook in its wing, giving it a gull like appearance that is different from other raptors. It is blackish-brown above, with most of its head white, except for a dark mask behind the eye, is white underneath, with a banded tail and long wings with dark spots at the wrist. An array of tiny spikes on each footpad helps the bird carry slippery, struggling fish to distant dining perches. Typically observed near sizable bodies of water, these large, rangy hawks do well around humans (Zeiner 1988).



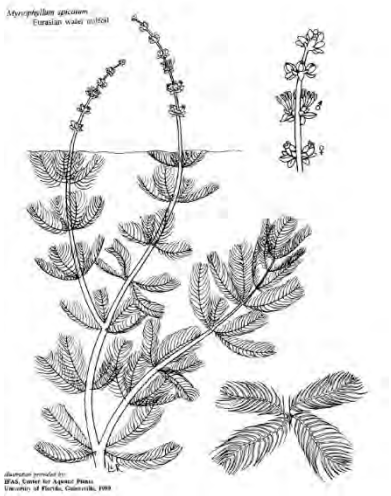
Osprey Photo - Courtesy “Mike” Michael Baird

Aquatic Plants Commonly Found in the Tahoe Keys Lagoons

The five most common aquatic plant and algal species that have been found in the Tahoe Keys lagoons are described in detail in this section.

Eurasian watermilfoil (*Myriophyllum spicatum* L.) and Northern watermilfoil (*M. sibiricum)*

This species is the most widespread aquatic nuisance plant in the United States. The plant can form a dense canopy at the surface of the water, out-competing other aquatic plants. Heavy infestations can lead to decreased levels of dissolved oxygen under the canopy and changes in pH, both of which can alter aquatic ecosystems by decreasing native species diversity and changing water quality parameters.



M. spicatum

Eurasian watermilfoil is an evergreen perennial plant that roots in sediment and grows completely underwater, typically at 15-foot depth but has been found as deep as 30 feet. The leaves are pinnately compound with 14 to 24 pairs of leaflets in groups of four at each stem node. Flowers form on short stems above the water surface and flowers produce up to four nutlets or seeds which disperse readily. Eurasian watermilfoil can also spread by forming new root crowns from rhizomes and can easily break at the shoot tips which creates fragments that move by wave action or by aquatic animals.

Eurasian watermilfoil is very similar in appearance to the native aquatic species, northern watermilfoil (*M. sibiricum*) and hybridization between the two species can occur. Both species spread readily by stem fragments formed naturally by abscission from the main plant or by breakage caused by wave action or feeding by waterfowl. These species can travel in boat ballasts, bait wells, boat trailers but introduction through the aquarium trade is also a contributor to its spread.

Curlyleaf Pondweed (*Potamogeton crispus* L.)

P. crispus

This species is found in all of the lower 48 states and is considered naturalized throughout this range.

Curlyleaf pondweed is a rooted perennial with a fast growth rate. The plant stem is very thin and long and can entrap swimmers. Curlyleaf pondweed aggressively out-competes native submerged vegetation. The plant has wavy-edged leaves which are green early in the growing season and turn red at the water surface. The leaves are oblong, one to three inches long, and are in an alternate arrangement along the stem. Curlyleaf pondweed typically is found in more shallow waters at three to six feet depth but can be found in clear waters as deep as 20 feet.

Curlyleaf pondweed reproduces primarily by turions and rhizomes but can also spread by stem fragments or seeds. Turions are modified asexual buds that form in spring to early summer prior to plant senescence. Seed germinations rates are low for this species. This species can overwinter with some green growth remaining above the sediment, thus giving these plants an advantage when temperatures rise and growth resumes in the spring. The spread is attributed to boating and fish hatchery activity (Stuckey 1979).

Curlyleaf pondweed forms dense mats at the water's surface which inhibits navigation and recreation. The dense mats limit light from reaching native vegetation and can inhibit oxygen exchange along the water column. These conditions reduce the populations of fish or aquatic invertebrates and can create conditions that promote mosquito habitat by removing predators and obstructing water flow.

Coontail (*Ceratophyllum demersum L.*)

C. demersum

This native aquatic plant is found nearly world-wide and throughout California up to 6,500 feet in elevation. In natural areas, coontail is considered beneficial and provides food and shelter to other aquatic species. However, it can develop very dense mats which inhibit water flow, interfere with recreation, and promote mosquito habitat. It is often considered a nuisance plant in relatively shallow lakes and ponds.

Coontail is a submersed plant that lacks true roots. It can exist as a free-floating plant or it can form modified stems and anchor itself to other aquatic plants. Young plants readily detach from soil.

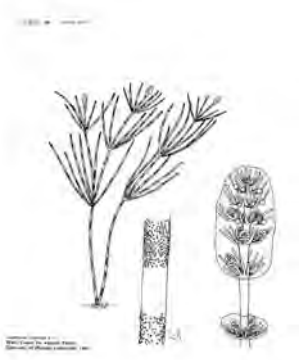
Coontail plants have slender stems with single branches at nodes. The leaves are dark green, forked, with small-toothed margins. Coontail reproduces vegetatively, by stem fragments and turions, and by seed, although in cold water, plants produce few to no seeds (DiTomaso 2003). Fruit and seed production have often been observed in the Keys lagoons during aquatic plants surveys.

Common Elodea (*Elodea canadensis*)

E. canadensis

Elodea is a native to North America and can inhabit waters to 8,500 feet in elevation. Elodea is an important component of aquatic ecosystems where it furnishes habitat and forage, although elodea can become a problem in nutrient-rich aquatic systems with elevated iron and phosphorous levels. Although a native plant in Canada and the lower 48 states, *Elodea* species have recently invaded several lakes in Alaska where it is not native.

Elodea grows best in water less than 15 feet with high light conditions and under certain conditions, such as high water clarity, Elodea can grow at greater water depths. It is a rooted aquatic plant that readily creates stem fragments that can be transported to new locations. Seedlings are rare. Elodea has dark green leaves, typically found in opposite pattern or three-whorled pattern at stem nodes. Turions can form at terminal growing tips (DiTomaso 2003).



Multicellular algae

Multicellular algae

Nitella species and *Chara* species are multicellular algae that appear to be rooted aquatic plants. Several species of the genus *Nitella* are found in the Tahoe Keys lagoons. *Nitella* is native and is common throughout North America. It is a green algae with branched filaments that have one or more forks that is generally found anchored to the substrate.

Several species of the genus *Chara* are found in the Tahoe Keys and Keys Marina. *Chara* is a green algae common in the western United States. The algae filaments have whorled and can be more than 12 inches long.

Filamentous algae

Filamentous algae are single celled organisms that form long chains of cells, or filaments. These filaments can form long strands and intertwine forming mats. Filamentous algae usually float to the surface and form large mats. Often there will be many species of filamentous algae present. Filamentous algae are not known to be a direct food resource for wildlife. Algae can also cause oxygen depletion that can increase the likelihood of fish kill (Lembi 2009).

Benthic Macroinvertebrates

BMI (also known as "benthos") are small animals living among stones, logs, sediments and aquatic plants on the bottom of streams, rivers and lakes. They are large enough to see with the naked eye (macro) and have no backbone (invertebrate) (WVDEP 2018). BMI act as an element of water quality monitoring. The taxonomic identification of a BMI community reflects conditions and changes in water quality as the species found in freshwater ponds, lakes, and streams are often extremely sensitive to changes in pollution (Azrina et. al 2006).

BMI species found within the Tahoe Keys Lagoons represent a community with a high tolerance to degraded water quality and typical of lake systems, is dominated by collectors, filterers, and grazers in varying proportions (TKPOA 2016d).

Special-Status Species in the Tahoe Basin

Several sensitive species are known to be present in the Tahoe Basin, but there are no recorded occurrences of these species within

the Tahoe Keys lagoons (CDFW 2014). Brief descriptions of the sensitive species in the region are given in this section.

Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*)

LCT is a member of the Salmonidae (trout and salmon) family, and is thought to be among the most endangered western salmonids.

LCT was listed as endangered in 1970 and reclassified as threatened in 1975 (USFWS 2014) and is considered extirpated from Lake Tahoe.

Like other trout species, LCT are found in a wide variety of cold-water habitats including large terminal alkaline lakes, alpine lakes, slow meandering rivers, mountain rivers, and small headwater tributary streams. Generally, LCT occur in cool flowing water with available cover of well-vegetated and stable stream banks, in areas where there are stream velocity breaks, and in relatively silt free, rocky riffle-run areas.

The LCT is endemic or native to the Lahontan basin of northern Nevada, eastern California, and southern Oregon. LCT currently occupies between 123 to 129 streams within the Lahontan basin and 32 to 34 streams outside the basin, totaling approximately 482 miles of occupied habitat. Self-sustaining populations of the species occur in 10.7 percent of the historic stream habitats and 0.4 percent of the historic lake habitats (USFWS 2014).

In the Lake Tahoe Basin, there have been attempts to reestablish both stream and lake populations. Many of the planted fish are consumed by non-native trout and LCT is considered to be extirpated from Lake Tahoe due to this predation. On-going maintenance is required in the headwaters of the Upper Truckee River (TERC 2014; CDFW 2015). Two LCT were captured in the Upper Truckee River in 2011 during a survey conducted by the US Forest Service. These fish were determined to be hatchery fish released by the Nevada Department of Wildlife earlier that year (USFS 2013).

Tahoe Yellow Cress (*Rorippa subumbellata*)

Tahoe Yellow Cress Photo Credit: USFWS

The Tahoe yellow cress is a federal candidate species for listing and is a California listed endangered plant. The habitat for this plant is coarse sand and sandy soils (often among cobbles or boulders) of active beaches, stream inlets, beach dunes, and backshore depressions, generally within a few feet of the local water table, in the shore zone of Lake Tahoe at elevations of 6,223 to 6,230 feet. It

occupies a narrow three meter-wide band on the shores of Lake Tahoe, where it apparently requires an interaction of soil moisture, low competition from other plant species and coarse sandy soil texture. This habitat is nearly eliminated during periods when high lake levels are maintained, but in drought years, when lake levels drop, the shoreline habitat is substantial (Pavlik 2002). The Tahoe Keys lagoons have fine-textured sediment in the bottom of the waterways, not the coarse sandy soils associated with Tahoe yellow cress habitat. There are several known populations of Tahoe yellow cress outside of the Tahoe Keys lagoons (Figure 6). The California Tahoe Conservancy has installed signage in the area to educate the public about this special-status plant and its habitat.

Figure 6. Tahoe Yellow Cress Occurrences near Tahoe Keys Lagoons

Willow flycatcher (*Empidonax traillii*)

The willow flycatcher is listed in California as endangered. It is a small bird that breeds in wet shrubby thickets and riparian woodland, particularly with willow and buttonbush (AOU 1998). It is a spring and summer resident in montane riparian areas and wet meadows from 2,000 to 8,000 feet in elevation. Breeding populations tend to occur in isolated mountain meadows of the Sierra Nevada and Cascades (Craig 1998). No suitable habitat for willow flycatcher is found in the Tahoe Keys lagoons, but suitable habitat is found in the nearby area.

Bald eagle (*Haliaeetus leucocephalus*)

A state endangered species, bald eagles prefer habitat near large areas of open water such as rivers, large lakes, and seacoasts. They tend to use areas away from human disturbance (Snyder 1993). The

Tahoe Keys lagoons do not provide the preferred habitat for nesting or areas for hunting, but bald eagles have been seen perching in large snags and nesting in trees in the area.

Sierra Nevada yellow-legged frog (*Rana sierrae*)

A state threatened and federally endangered species, Sierra Nevada yellow-legged frog is patchily distributed at high elevation lakes and slow-moving streams typically above 6,000-foot elevation in the Sierra Nevada range north of the Kern River watershed, and over the eastern crest of the Sierra into Inyo and Mono counties at the southern-most extent (USFWS 2013). The Tahoe Keys lagoons do not provide suitable habitat for this species.

Bank swallow (*Riparia riparia*)

The bank swallow is listed as a state threatened species. It prefers nesting in vertical banks and bluffs with alluvial soil often near rivers and lakes with erosional forces. The Tahoe Keys lagoons do not provide suitable habitat for this species.

2.0 PURPOSE OF THE INTEGRATED MANAGEMENT PLAN FOR AQUATIC WEEDS

Like numerous other recreational lakes, Lake Tahoe is experiencing an increase in the presence of non-native plant and animal AIS (Getsinger 2014; TRPA 2014). Non-native organisms have great potential to not only harm the natural ecosystems of the Basin but the economy of the region as well through impacts due to loss of recreational opportunities and increased costs for maintenance to boats and piers. Non-native species also change the nutrient load of the water and can have detrimental effects on water quality and clarity.

2.1 AIS of Concern

Aquatic invasive species of concern in Lake Tahoe are found primarily in the near-shore zones where shallow waters have warmer temperatures, sufficient nutrients, and favorable habitat conditions. Over the last few decades, increased efforts have been made to assess and implement control measures to reduce the populations of invasive, non-native species and to prevent the introduction of other non-native species because they displace native organisms and negatively affect water quality.

The Lake Tahoe Aquatic Invasive Species Management Plan (Regional Plan), first published in 2009, was updated in 2014. The goals of the Regional Plan are to:

- Prevent new introductions of AIS to the Lake Tahoe Region
- Limit the spread of existing AIS populations in the Lake Tahoe Region, by employing strategies that minimize threats to native species, and extirpate existing AIS populations when possible
- Abate harmful ecological, economic, social and public health impacts resulting from AIS

The Regional Plan is structured around the following objectives:

- Oversight and internal coordination
- Prevention
- Monitoring, detection and response
- Long-term control

The Regional Plan identified over 30 non-native aquatic species of plants and animals that have been introduced into the Tahoe region, and identified an additional 17 species of plants and animals that, if introduced to the region, could become established and reach nuisance levels.

Table 2. Established Non-native Species in the Tahoe Region

Type	Name	Scientific Name
Plants	curlyleaf pondweed	*Potamogeton crispus*
	Eurasian watermilfoil	*Myriophyllum spicatum*
	rock snot	*Didymosphenia geminate*
Introduced fishes	largemouth bass	*Micropterus salmoides*
	smallmouth bass	*Micropterus dolomieui*
	Bluegill	*Lepomis macrochirus*
	brown bullhead	*Ameiurus nebulosus*
	black Crappie	*Pomoxis nitromaculatus*
	brook trout	*Salvelinus fontinalis*
	brown trout	*Salmo trutta*
	Kokanee salmon	*Oncorhynchus nerka*
	lake trout	*Salvelinus namaycush*
	rainbow trout	*Oncorhynchus mykiss*
Other Species	Asian clam	*Corbicula fluminea*
	signal crayfish	*Pacifastacus leniusculus*
	American bullfrog	*Rana catesbeiana*
	gill maggot	*Salmincola californiensis*

Table 3. Non-native Species Not Yet Established in the Lake Tahoe Region

Type	Name	Scientific Name
Aquatic Plants	Brazilian Egeria	*Egeria densa*
	Fanwort	*Cabomba caroliniana*
	giant salvinia	*Salvinia molesta*
	Hydrilla	*Hydrilla verticillata*
	oxygen weed	*Lagarosiphon major*
	parrot feather	*Myriophyllum aquaticum*
	South American spongeplant	*Limnobium laevigatum*
	water chestnut	*Trapa natans*
	yellow flag iris	*Iris pseudacorus*
	yellow floating heart	*Nymphoides peltata*
Other Species	New Zealand mudsnail	*Potamopyrgus antipodarum*
	quagga mussel	*Dreissena bugensis*
	zebra mussel	*D. polymorpha*
	spiny waterflea	*Bythotrephes longimanus*
Fishes	white Crappie	*Pomoxis annularis*
	northern pike	*Esox lucius*
	Mosquitofish	*Gambusia affinis*

Currently, there are a number of AIS prevention and control activities in place in and around Lake Tahoe including education and outreach to the public, volunteer programs, and governmental regulation. The Lake Tahoe Aquatic Invasive Species Coordination Committee (LTAISCC) facilitates collaboration on AIS prevention, control and early detection by sharing information, standardizing treatment methods and establishing data collection, setting project priorities and identifying funding opportunities for control activities. Working with the LTAISCC, TRPA, and TRCD coordinate the Lake Tahoe Watercraft Inspection Program to prevent the introduction of new AIS. TRCD has also been working to control aquatic macrophytes using diver-assisted suction and placement of benthic barriers in Emerald Bay and in the Truckee River.

The 2015 LTAIS Implementation Plan

The Lake Tahoe Aquatic Invasive Species Implementation Plan (Implementation Plan) was published in July 2015 (Wittman 2015) as a companion document of the Regional Plan. The Implementation Plan provides information on establishing priority species and locations for AIS control work, and information on controlling and reducing the impacts of the 30 AIS identified in the Regional Plan.

In the Implementation Plan, AIS for priority control work were selected using two primary criteria. First, species were considered based on their ranking in the Regional Plan as "…nonindigenous species perceived to cause significant damage or harm in the Lake Tahoe Watershed…" Secondly, the Lake Tahoe AIS Coordination Committee helped refine the list of priority species to those for which control was determined to be feasible in the Lake Tahoe Basin or those species with significant unwanted effects on restoration goals within the Tahoe Basin (Wittman 2015). Using these criteria, Eurasian watermilfoil and curlyleaf pondweed were determined in the Implementation Plan to be the two priority invasive aquatic plant species for which there are feasible control actions.

Priority locations for AIS control work are also described in the Implementation Plan. Locations were evaluated on many factors including fish-plant interactions, the size of the infestation at a site, human use of the site, and the location of the infestation in the Tahoe Basin. Using these metrics, the Tahoe Keys lagoons, along with several other areas around Lake Tahoe, were identified in the Implementation Plan as areas of the highest priority for AIS control work due to the "…immensity of nuisance aquatic plant infestations…" The Tahoe Keys lagoons were given the highest site prioritization in part due to the recreational levels in the lagoons. The Implementation Plan further stated that targeting removal of AIS from the highest priority sites would reduce the potential for proliferation of these species in the Lake.

The priorities identified in the Implementation Plan for both the aquatic plant species to be controlled and for areas to be treated underscore the importance of controlling aquatic macrophytes in the Tahoe Keys lagoons.

2.2 Aquatic Invasive Plants and Their Impacts

Submerged plants are critical to a well-structured fish assemblage. They provide protection for small fish from predators and provide habitat for large numbers of invertebrates for small fish to eat. Submerged plants also provide an important food source for many species of waterfowl in the form of vegetation-dwelling invertebrates or the plants themselves and can affect water quality, oxygenate the water and provide for long-term storage of nutrients and carbon.

Left unchecked, aquatic plants can create a dense canopy that changes habitat conditions for native fish, impedes water flow in the water body, disrupts navigation, creates hazardous conditions, and discourages recreational use of the waters. Invasive aquatic macrophytes alter the structure of the ecosystem resulting in a decrease in biodiversity of plants, animals, and invertebrates. Dense canopies can also physically decrease the natural pattern of water mixing.

Uncontrolled growth of aquatic macrophytes can result in a decrease in water quality. In conditions with a dense cover of aquatic macrophytes, pH of the water has a tendency to increase. Dense aquatic plant canopies also change the chemistry of the sediment layers or hydrosoil by reducing the oxygen levels, which in turn promotes the release of phosphate from soil particles (Søndergaard 2003).

Rooted aquatic macrophytes have been associated with increased nutrient loading in the water column. Aquatic plants have the ability to take up nutrients through their roots or shoots, depending on nutrient demand and availability. Eurasian watermilfoil and curlyleaf pondweed utilize rhizomes and are comparatively more efficient at sediment uptake of nitrogen and phosphorus than other rooted aquatic macrophytes. Free-floating plants, such as coontail, lack roots and absorb necessary nutrients from the water column as they have no connection to nutrient-containing sediment (Angelstein 2008).

Absorbed nutrients are translocated and stored in various locations throughout the plant, although it has been found that plant shoots tend to have higher concentrations of nitrogen and phosphorus than roots (Walter 2000). These nutrients are used in a variety of metabolic processes and are released into the surrounding environment with senescence and decay (Smith 1990). In general, 50% of nitrogen and phosphorus are resorbed to roots or other live plant parts upon leaf senescence. Nutrients not resorbed by the plant

are deposited in litter where they are made available to other plants upon the decomposition and subsequent mineralization of detritus (Aerts 1996).

Plant tissues of common elodea and Eurasian watermilfoil have been reported to release phosphorous to the water column, regardless of photoperiod, under conditions of elevated pH and reduced levels of dissolved oxygen that can occur in dense canopy environments. It was also found that these two plants release oxygen, carbon dioxide, nitrogen, phosphates, silica, and other organic compounds during photosynthesis as well. The rates of uptake and release of phosphorus by aquatic plants was determined to be driven by light availability, the rate of photosynthesis and plant respiratory processes. Most research on the cycling, translocation, and leaching of phosphorus has been conducted using Eurasian watermilfoil and Elodea and tracer phosphorus (Walter 2000). There is insufficient data on nutrient cycling undergone by curlyleaf pondweed and coontail.

2.3 Historical Perspective: Controls Used in the Tahoe Keys Lagoons to Control Aquatic Invasive Plants

Eurasian watermilfoil was confirmed in Lake Tahoe over 30 years ago (Anderson 1996) and curlyleaf pondweed was confirmed in 2003 (Anderson 2003). Surveys of Lake Tahoe have shown that size and locations of the infestations of the two plants has changed somewhat over time, but that the overall trend shows that infestations of these plants have increased substantially.

TKPOA began aquatic plant control work in the 1980s using mechanical harvesters to keep navigation channels clear. Maintenance activities and costs to remove aquatic plants have increased dramatically over the years due to an increased volume of plant growth. Current management costs are approximately $2,900 per acre, which includes equipment and disposal of plant material that must be transported out of the Tahoe Basin. The volume of weeds removed has increased to approximately 10,000 or more cubic yards per year for the roughly 145 acres of the Tahoe Keys lagoons that were harvested during 2016.

Other Aquatic Plant Control Methods Used in the Tahoe Keys Lagoons

Floating, solar-powered vertical circulation devices known as Solar Bees© were installed at four locations in the Marina Lagoon from

2008 to 2010. There was no detectable decrease in the growth of coontail, Eurasian watermilfoil, or curlyleaf pondweed. In 2008, a study of Solar Bees©, including bioassays of both plant tissue and sediments, showed no effect on the growth of Eurasian watermilfoil under greenhouse conditions (Anderson 2008).

TKPOA collaborated with TRCD and TRPA in the Tahoe Keys Aquatic Plant Management Research Project from 2011 to 2013. One goal of this project was to determine the efficacy and feasibility of non-chemical control of Eurasian watermilfoil and curlyleaf pondweed using benthic or bottom barriers to suppress aquatic plant growth. The study found that the bottom barriers provided short-term control of aquatic plants over a limited area but that they allowed aquatic plants to quickly recolonize the area that had been treated (TRCD 2014a).

In 2017, TKPOA conducted a larger scale test of bottom barriers in the lagoon between White Sands and Balboa Drives. This test covered approximately three quarters of an acre and the barriers were kept in place for three months. Like the previous study, it was determined that the barriers allowed for temporary control but the area would likely recolonize quickly due to proximity of other aquatic invaise plant populations and a high rate of sediment deposition (TKPOA 2018).

2.4 Current Status: Aquatic Invasive Plants in Tahoe Keys Lagoons

Species Composition and Density of Aquatic Invasive Plants

Surveys of aquatic plants in the Tahoe Keys lagoons were completed in 2009 and 2011. Beginning in 2014, TKPOA began conducting annual aquatic plant surveys of the Tahoe Keys lagoons. In 2014, the survey characterized aquatic plant coverage in the Main and Marina Lagoons as a nearly closed canopy consisting primarily of Eurasian watermilfoil and coontail. Eurasian watermilfoil was found in higher densities in shallower waters near bulkheads and shorelines whereas coontail was found in higher densities in deeper channels (TKPOA 2014a).

Figure 7. Coontail Composition, 2015

In 2015, the survey protocol was improved by including hydroacoustic sampling to determine the volume of plant material, or biovolume, present. The survey results showed that the aquatic plant canopy covered over 75% of the Marina Lagoon and that the aquatic plant canopy was slightly denser in the Main Lagoon (Figure 8). The species composition in 2015 was similar to that seen in previous years (TKPOA 2015).

Figure 8. Biovolume of Weeds, 2015, Main Lagoon

The 2016 and 2017 surveys showed a significant increase in the presence of curlyleaf pondweed. This increased presence is seemingly exponential and concerning since curlyleaf is often more difficult to control. Turions released from mature plants during the summer have the ability to stay dormant in the sediment layer until growing conditions are more ideal.

When compared to previous surveys, survey data show that the relative abundance of Eurasian watermilfoil and curlyleaf pondweed has been increasing over the years. In 2017, Eurasian watermilfoil, curlyleaf pondweed, and coontail were the most common aquatic macrophytes growing in the Tahoe Keys. The Marina Lagoon showed low biodiversity with two plants making up the majority of the canopy while the Main Lagoon had a greater diversity of plants.

In addition to the annual plant survey in 2017, it was also noted by water quality department staff that coontail was very abundant towards the end of the summer season. The plumes proved to be problematic in some instances and made navigation difficult in some areas.

Impacts of Mechanical Harvesting

Mechanical harvesting of aquatic plants (See Chapter 3.1) is the primary control method that has been used in the Tahoe Keys lagoons. This method creates viable plant fragments at a much higher rate than what occurs under normal conditions with boating, bird foraging, or other actions. In 2014, TKPOA conducted a study of mechanical harvesting practices (TKPOA 2014b). The study reported that mechanical harvesting increased the numbers of viable aquatic plant fragments by 30 to 45% over the background numbers.

2.5 Purpose of the Integrated Management Plan for Aquatic Invasive Weeds, Goals and Objectives of the Plan

The Tahoe Keys lagoons are used by many people for recreation and scenic enjoyment and the area provides a broad range of activities and opportunities to enjoy Lake Tahoe. Excessive growth of aquatic plants has impaired the waterways of the Tahoe Keys lagoons and the dense canopy of aquatic plants has reached nuisance status. The maintenance required keeping the waterways safe and navigable and the associated costs of this maintenance have increased dramatically over the years due to the increased volume of aquatic plants which must be removed. Aquatic plants can be transported from the immediate area of the Tahoe Keys lagoons by wave action, currents, on boats, or by wildlife to new areas where they may become established and create new populations of aquatic plants that require control. A plan that provides for long-term management of aquatic plants is needed to maintain recreational safety, improve water quality, and to improve habitat for native species of the Tahoe Keys lagoons. Implementing such a plan will protect the beneficial uses of the waters of the Tahoe Keys lagoons.

The Purpose of the IMP is to help protect the ecology, enhance the recreational and aesthetic qualities, and to maintain the commercial uses of Lake Tahoe by integrating the methods of aquatic plant control that have been approved for use in the Tahoe Keys lagoons and improving the efficiency and efficacy of those methods.

Two goals are defined in this IMP that fulfill the Purpose of the IMP. Objectives that support these goals were used to establish criteria by which aquatic invasive plant control methods will be evaluated in the Adaptive Management Review Program (Chapter 4).

Goal 1 and its Objectives come from the Waste Discharge Requirements (WDRs) issued to the Tahoe Keys Property Owners Association:

Goal 1: Fulfill the Objectives identified by the Lahontan Board in the Waste Discharge Requirements issued to the Tahoe Keys Property Owners Association under Adopted Board Order R6T-2014-0059.

Objectives from the WDRs:

1. **Eliminate spreading of AIS from the Tahoe Keys to greater Lake Tahoe.**

Aquatic plants are known to readily spread by plant propagules, which include both sexual reproductive structures, such as seeds, and vegetative structures and viable fragments. Invasive aquatic plants have infested marinas throughout Lake Tahoe. Under this objective, the IMP strives to reduce one of the potential sources of these propagules, those from the Tahoe Keys lagoons, by reducing the population and density of nuisance aquatic plants and by improving control methods to reduce the potential to generate viable plant fragments that can be transferred from the Tahoe Keys lagoons to Lake Tahoe.

2. **Enhance the overall water quality of the Tahoe Keys lagoons and Keys Marina thereby improving Lake Tahoe water quality and associated clarity.**

The dense canopy of aquatic macrophytes that have been reported in the Tahoe Keys lagoons can lead to changes in water quality parameters such as increased pH and the resultant release of nutrients such as phosphate from sediments due to this increase and due to the release of nutrients upon senescence and decomposition of the plants. The Tahoe Keys lagoons are directly connected to Lake Tahoe at the East Channel of the Marina Lagoon and the West Channel of the Main Lagoon. Reductions in nutrient release in the Tahoe Keys lagoons will result in a decrease of the potential dissipation of these nutrients to Lake Tahoe as well as improve the water quality parameters in the Tahoe Keys lagoons themselves.

3. **Reduce habitat for non-native fish and enhance habitat for native fish in the Tahoe Keys lagoons and Keys Marina.**

The density of aquatic plants in the Tahoe Keys lagoons has shifted the benthic habitat toward supporting introduced species of warm-water fish, such as bass and bluegill, to the detriment of native fish, such as the Lahontan redside and Mountain whitefish. Under this objective, the IMP strives to reduce the plant canopy formed by non-native and invasive aquatic plants that harbor the non-native fish species in favor of native fish and benthic species.

4. **Restore and maintain established beneficial recreational uses, including water contact safety in the Keys lagoons and commercial uses in the Keys Marina.**

Aquatic invasive plants can adversely affect navigation when stems entangle boat rudders, propellers and clog cooling systems. During the summer months, ongoing maintenance operations to keep the waterways open disrupt boating activities and impact the visual aesthetics of the Tahoe Keys lagoons. Under this objective, the IMP strives to improve boating and recreational access of the Tahoe Keys lagoons by both establishing and maintaining adequate vessel hull clearance to allow for safe boating and by minimizing removal work which disrupts recreational activities.

5. **Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants.**

By using best available technology to assess conditions, personnel and resources can quickly be directed to where they are needed most. Under this objective, the IMP strives to improve control work by consistently utilizing accurate survey methods, such as hydroacoustic sampling, which can report real-time data so that control work can be effectively scheduled. By using GPS equipment, maps can be made that show where work has been completed and reference points established to allow objective evaluation of the control work.

Control methods for aquatic invasive plants that are currently approved for use in the Tahoe Keys lagoons are described and reviewed in Chapter 3, and the implementation plan for Year 1 (2016) is given in Chapter 4.1. The IMP combines all the feasible and approved methods for aquatic plant control in the Tahoe Keys lagoons.

The WQC developed Goal 2 and its supporting objectives to underscore the fact that the IMP is a working document that will be subject to review and changes:

Goal 2: To support improvements and updates to the IMP, TKPOA will continue to refine existing methods of aquatic plant control and to research new, safe, cost-effective methods to control aquatic invasive plants. The Adaptive Management Program Committee and the Lahontan Board will use established, objective criteria to evaluate these methods and propose effective, feasible methods for inclusion in updates to the IMP.
Objectives for Goal 2 are:

1. **Identify and confirm safety and efficacy of proven novel aquatic invasive plant control methods by reviewing scientific literature and reports of these methods used under real world, operational conditions.**

2. **Conduct and monitor small-scale demonstrations of localized control methods in defined areas of the Tahoe Keys lagoons. These small-scale demonstrations may include methods not specified as control measures in the WDRs but will be conducted under the appropriate authorization of and permits issued by the Lahontan Board.**

TKPOA plans to meet the Objectives of Goal 2 with a program of research of new and novel methods of aquatic invasive control and an on-site testing program to demonstrate efficacy of any new method proposed for inclusion in updates to the IMP.

Chapter 4.2 provides a complete description of the research and testing program. All proposed testing will be done under approval of and with proper permits from applicable resource agencies.

2.6 Development of the IMP and Public Involvement

Removing aquatic plants from the Tahoe Keys lagoons has been a seasonal maintenance practice for TKPOA since the 1980s. After 2007, the quantity of aquatic plant material removed from the Tahoe Keys lagoons began increasing dramatically (Figure 7). TKPOA began researching additional aquatic plant control methods and worked with TRCD beginning in 2011 to test bottom barriers and to analyze conditions in the Tahoe Keys lagoons to determine the factors that could be influencing the growth of the aquatic weeds.

Realizing that the problem of uncontrolled growth of aquatic plants was escalating, the WQC began developing an integrated management plan in 2013. The WQC retained the expertise of aquatic plant expert Lars Anderson, Ph.D., known for his work on aquatic macrophytes at Lake Tahoe and the Tahoe Keys lagoons to help identify suitable control methods for the Tahoe Keys lagoons. TKPOA also retained Sierra Ecosystem Associates (SEA) to assist Dr. Anderson. The WQC reviewed aquatic plant control methods and several of the many integrated management plans for aquatic plants that have been developed throughout the United States, including those developed for Big Bear Lake and Clear Lake in California, Lake Stevens in Washington, Chetek Lakes and Balsam Lake in Wisconsin. Based on this initial information gathering, the WQC

developed an annotated outline of their plans for an integrated management plan for the Tahoe Keys lagoons.

In 2014, the Lahontan Board issued the WDRs to TKPOA.

Among the findings, the WDRs specified that TKPOA write an integrated management plan to address controlling aquatic weeds in the Tahoe Keys lagoons. To fulfill this requirement, and to continue their work on the IWMP, the WQC again retained Dr. Anderson and SEA to develop the Draft IWMP and to interact with the regulatory and resources agencies in the Lake Tahoe area.

TKPOA invited five experts in the field of aquatic biology to serve as experts to review the Draft IWMP. The Expert Review Panel members were:

- Joe DiTomaso, Ph.D., UC Davis Cooperative Extension, Panel Chairperson
- Sudeep Chandra, Ph.D., University of Nevada, Reno
- Joel Trumbo, California Department of Fish and Wildlife
- Patrick Akers, Ph.D., California Dept. of Food and Agriculture
- Kurt Getsinger, Ph.D., US Army Engineer Research and Development Center

Dr. Anderson worked closely with the Expert Review Panel to evaluate all aquatic plant methods to determine their suitability and potential efficacy in the Tahoe Keys lagoons.

For the IWMP, the WQC also solicited input from numerous resource agencies and non-profit organizations involved with AIS control in Lake Tahoe and the surrounding Basin area. TKPOA also held extensive consultations with the Lake Tahoe AIS Coordinating Committee, Lahontan Board, and TRPA in developing the Draft IWMP.

This effort culminated in the release of the Draft IWMP for public review in August 2015. The Draft IWMP was posted on the website www.keysweedsmanagement.org and TKPOA hosted a public meeting on August 11, 2015. Dr. Lars Anderson and the independent Expert Review Panel presented the Draft IWMP and answered questions from the members of the public attending the meeting.

While most of the people attending the meeting strongly supported the Draft IWMP, several voiced concerns about the Plan including TKPOA's proposed use of aquatic herbicides.

Over 50 written comments were received on the Draft IWMP between August and December 2015. Some comments, including those from the Lahontan Board, suggested the need for the plan to more fully consider a range of control methods.

In light of the comments and concerns on the Draft IWMP from the public and the Lahontan Board, TKPOA decided to revise the Draft IWMP. This resulted in the Integrated Management Plan for Aquatic Weeds (IMP) submitted to the Lahontan Board in May 2016. The May 2016 IMP described an integrated approach to aquatic plant control in the Tahoe Keys lagoons using the currently approved methods listed in the WDRs, which are: mechanical harvesting, placement of bottom barriers, and public education and outreach.

The IMP also described a two-year research and testing program with an Adaptive Management Review program to:

- Identify and evaluate additional new and novel methods for aquatic plant control
- Investigate aquatic control methods proposed by the public
- Gather information to answer questions posed by the public

On August 18, 2016 the Lahontan Board informed TKPOA that the May 2016 IMP was conditionally approved with the stipulation that all references to the proposed use of aquatic herbicides be removed from the text of the IMP and used only in an appendix (See Appendix B).

For this IMP, TKPOA has placed all text regarding the proposed use of aquatic herbicides in Appendix A. This IMP retains the integrated approach to aquatic plant control and the Adaptive Management Review program described in the May 2016 IMP

The IMP will be updated and submitted to the Lahontan Board in January 2017. The update will include summaries of the 2016 control activity, results of field testing, and the results of research on new methods of aquatic plant control.

As described in Section 1.2, TKPOA is only one of several entities that own or manage the lands and waters within the Tahoe Keys. At the outset of the IMP project, the goal was to include all the owners or managers of the surrounding properties and to have them participate in and share the costs of developing the plan. To date, the Tahoe Keys Beach and Harbor Association is the only other entity that is helping with the costs for the extensive planning, public involvement, and field studies associated with the plan.

3.0 APPROVED METHODS OF PLANT CONTROL: ADVANTAGES AND DISADVANTAGES

The WDRs issued to TKPOA permit the use of several methods of aquatic weed control. Descriptions of each of the approved methods, along with summaries of their advantages and disadvantages, are given in this chapter.

3.1 Mechanical Control: Harvesting

Mechanical control is the most commonly used method to control invasive aquatic plants. TKPOA has used mechanical harvesters for aquatic weed control since the 1980s to maintain navigation in the Tahoe Keys lagoons.

Figure 9. Mechanical Harvester

Mechanical harvesting equipment ranges from small hand-held cutting devices to large boat-mounted, hydraulically-controlled cutting, conveyance and transport systems. The small systems are useful around space-constrained areas. The larger, boat-mounted systems typically have removal systems to collect plant fragments and are the most practical for large areas such as the Tahoe Keys lagoons. Large systems both cut and remove the plants as part of the same operation. Cut plants are off-loaded to an on-shore carrier and taken off-site for disposal. Depending on site conditions, these machines can cut the plants approximately five to 10 feet below the surface of the water. Obstructions such as docks and pilings prevent

the use of large mechanical harvesters. The plants in target areas must be harvested one or more times during the growing season to maintain acceptable conditions.

Advantages

- Mechanical harvesting offers the immediate improvement of access to the waterway for boating and other recreation. Large harvesting machines can remove thousands of pounds of plant material from a waterway. For example, in the Tahoe Keys lagoons, approximately 10,000 to 20,000 cubic yards of plant material is removed and hauled off-site annually.
- Mechanical harvesting does not require a permit and there are no requirements for monitoring.
- Efficient mechanical harvesting operations can remove some nutrients sequestered in the harvested plant biomass and over time can reduce the internal loading of dissolved phosphorous (Greenfield 2004).

Disadvantages

- Harvesting creates thousands of viable plant fragments per acre harvested and releases viable plant propagules that can disperse to uninfested areas by waterfowl, wind and water movement, and boat traffic.
- Harvesting is a non-selective operation. This lack of selectivity can negatively impact desirable, native aquatic species.
- The physical actions from these operations can cause direct harm to fish, amphibians and invertebrates and other organisms through injury or mortality, or by removing cover that protects native fish from prey. These impacts are directly related to the scale of operations and to the abundance and occurrence of non-target organisms in the treatment area.
- Mechanical harvesting can impact water quality by increasing turbidity and releasing nutrients
- Mechanical cutting is conducted during the early rapid growth phase and continuing growth period of the plants throughout the summer. Cutting plants during these periods can stimulate their growth and also cause more lateral growth or side-branching to occur which results in a denser plant canopy.
- Disposal costs can be expensive. Often plant material must be hauled to locations remote from the harvested area and disposal costs can constitute a large part of the budget.

Suitability to Tahoe Keys Lagoons

Mechanical harvesting has been the primary means of control used in the Tahoe Keys lagoons and it is anticipated that some harvesting will continue to be used as part of the integrated management approach. The WDRs issued to TKPOA specify that Best Management Practices (BMPs) be developed for controlling plant fragments generated by mechanical harvesting.

Harvesting methods in the Keys lagoons were analyzed in the 2014 study, "Characterization of Aquatic Plant Fragments in the Tahoe Keys Lagoons" (TKPOA 2014b). The results of this study showed that harvesting increases numbers of fragments by 50 to 100% and increases the size of fragments that are found compared to pre-harvest samples. Recommendations and modifications for standard mechanical harvesting machines made in the 2014 study were: modifying cutting bar depth, improving the methods of collecting fragments during operations, removing fragments from dead-end coves and down-wind sites, selecting harvest sites according to prevailing winds, as well as using real-time information on aquatic plant conditions in the Tahoe Keys lagoons to efficiently direct harvesting machines to problematic areas.

3.2 Placement of Bottom Barriers

Bottom barriers are typically large sheets of an impermeable or semi-permeable synthetic or natural material that is placed directly on the plants and anchored in place with weight. Synthetic barriers may be polyethylene, PVC, or woven material permeable to gasses but not to light. Under the WDRs issued to TKPOA, up to five acres in the Tahoe Keys lagoons may be treated using bottom barriers per year and the barriers must be removed at the end of the growing season.

Figure 10. Jute Bottom Barrier

Advantages

- Bottom barriers offer effective control of aquatic plants and potentially can provide control over several growing seasons, if left in place.
- Bottom barriers can be placed under docks or piers that otherwise may be difficult areas to treat with other methods.
- Once in place, bottom barriers afford immediate relief from the impacts of excessive, nuisance aquatic plants.

Disadvantages

- Plant growth is suppressed only as long as barriers are in place. Once removed, plant densities can return to pre-treatment levels if plant propagules re-infest the treated area.
- Control is non-selective for nuisance as well as native plants.
- There have been reports of aquatic plants recolonizing through natural jute barriers but this appears to be uncommon. Aquatic plants can also recolonize in sediment deposited on the top of the barrier.
- Bottom barriers cover the benthic habitat, which results in a temporary loss of habitat for BMI while vegetation is decomposing, due to an increase in ammonia and a decrease in dissolved oxygen. Studies have shown that populations of

these invertebrates can quickly recover after barriers are removed (Ussery 1997, TRCD 2014a).

- Bottom barriers can be dislodged by wave action from boating activity.
- Large-scale placement requires using trained divers, which makes it comparatively expensive. TKPOA utilized a diving company to install a large area of bottom barriers in 2017 which equaled approximately $76,500 per acre.

Suitability to Tahoe Keys Lagoons

Bottom barriers have been widely used in the US, at Lake Tahoe, and in the Tahoe Keys lagoons. TRCD conducted a three-year study in the Tahoe Keys lagoons using bottom barriers to control the growth of aquatic plants (TRCD 2014). The study showed that nuisance aquatic plant growth was suppressed in the short term (less than one year) but that recolonization over the subsequent two growing seasons resulted in aquatic plant densities similar to what was found in untreated areas. Bottom barriers were more effective in controlling Eurasian watermilfoil at Emerald Bay when they were used as part of TRCD's Lake-Wide Aquatic Invasive Plant Control Project. There are limitations to the use of bottom barriers in the Tahoe Keys lagoons. Compared to Emerald Bay, the water is relatively shallow and there is often a high level of recreational boat traffic. Bottom barriers can be readily dislodged by wave action even in areas where the boat speeds are slow. Once installed, bottom barriers should be inspected regularly and re-secured if needed.

The WDRs issued to TKPOA by the Lahontan Board currently allow a maximum of five acres of bottom barriers to be installed at any time in the Tahoe Keys lagoons. The WDRs require removal at the end of the growing season (LRWQCB 2014). In 2015, TKPOA developed a permitting system for individual homeowners to install bottom barriers around private docks in the Tahoe Keys lagoons. The program met with limited success and several improvements to the program were made for the 2016 and 2017 seasons. The program still has limited success due to the dense infestation in the Keys which quickly repopulates areas where bottom barriers were used.

3.3 Diver-Assisted Dredging or Diver-Assisted Suction Removal of Aquatic Plants

This method requires trained personnel using specialized equipment to remove aquatic plants from a treated area. The divers, or in some cases snorkel crews, carefully dislodge rooted plants from the sediment and guide them into a suction device that is mounted on a floating platform or barge which also carries the pumps necessary to create the suction. The plants are drawn up to the surface and then trapped in a sieve on the barge. Water taken up by the process is returned at some distance away from where the diver is working. Unlike dredging, the sediment is not removed directly by this action: the divers manipulate the suction hose to stay away from direct contact with the sediment. Typically, after sieving, the plants are bagged and disposed off-site.

Figure 11. Diver-Assisted Suction Removal

Advantages

- A skilled diver can avoid removing non-target plants and most non-target animals (except those attached to the plants) making this a selective control method.
- Thorough operations can be extremely effective in removing all or nearly all viable plant propagules.
- Eradication can be complete after two to three treatments during the growing season.

Disadvantages

- Divers must carefully dislodge plants while avoiding direct removal of sediment.
- The process can cause unacceptable increases in turbidity, requiring that operations cease until turbidity declines below thresholds established by the permit issued for the control work.
- Installing screening devices such as turbidity curtains may be required to isolate the treatment.
- There are potential hazards to divers from low visibility in the water, boat traffic, and inadvertent impacts include fish mortality.
- Treatment may be temporary if aquatic plant propagules enter from another site.

Suitability to Tahoe Keys Lagoons

Diver-assisted suction removal is used successfully at locations in California and outside the state. In California, TRCD has used this method to remove Eurasian watermilfoil at Emerald Bay as part of the Lake-Wide Aquatic Invasive Plant Control Project. TRCD plans to include it in their on-going work in the Tahoe Basin.

At Emerald Bay, TRCD was able to assure diver-safety by excluding boat traffic from the treatment area while the divers were on-site and TKPOA would need to use the same safety measures for work in the lagoons.

Unlike the coarse sediment layers of Emerald Bay, the Tahoe Keys lagoons have unconsolidated, fine sediment layers which increases the likelihood that turbidity could quickly increase above threshold levels allowed under permits. Turbidity curtains would be required to retain suspended material in the treatment area and poor visibility could present a problem during operations until turbidity levels drop.

Diver-assisted suction could be used at the Tahoe Keys lagoons under an existing dredging permit issued in 2015 for maintenance work and could prove particularly useful at sites that are not-well suited for other methods of control, such as around docks or other submerged obstructions. Given the recreational use of the lagoons, the need for diver safety by excluding boats from the treatment area, and the need to contain turbid water, use of diver-assisted suction would need to be timed carefully to minimize impeding navigation of the lagoons.

3.4 Hand-pulling

Aquatic plants can be removed from waterways by pulling out the plant, including the roots and other regenerative plant parts, and then capturing and disposing of the plant material in a suitable manner. Hand-pulling is best used in small-scale removal projects in shallow water where the plants can easily be identified and reached. In waters deeper than three feet, hand-pulling requires divers to reach and remove rooted plants. Success is dependent on the sediment type, visibility and proper identification of species. Some species can easily fragment and produce small pieces that are not easily captured and removed (SFEI 2004).

Advantages

- If all regenerative plant parts are removed during treatment, this method can greatly reduce regrowth in the treated area.
- In shallow waters, hand-pulling can be an effective and comparatively inexpensive method to remove aquatic plants.
- In deeper waters, using trained divers can be effective in reducing the biomass of nuisance aquatic plants.
- If water clarity is good, impacts to non-target species, such as native plants and animals, is minimal during treatment.

Disadvantages

- This is a slow and labor-intensive method of control.
- Reduced visibility in turbid water can impede removal of nuisance, target plants.
- Using trained divers with specialized scuba equipment increases the cost of hand-pulling and is generally not deemed appropriate for deep waters with dense canopies of aquatic plants due to unsafe diving conditions.
- Turbidity could increase to unacceptable levels when sediments are disturbed as the plants are pulled from the sediment.
- Increased nutrient levels in the water could result if significant amount of decaying plant material is left behind.
- Plant fragments and propagules that are not captured during treatment can drift from the area or can re-infest the treated area.

Suitability to Tahoe Keys Lagoons

Homeowners are not discouraged from hand-removing weeds from around their docks or from the shoreline of their property as long as this work can be done safely. However, the waters of the Tahoe Keys lagoons are typically deeper than three feet and are not safely accessible for hand-pulling work except by trained scuba divers. The dense aquatic plant canopy creates unsafe free-diving conditions. The aquatic plants can easily fragment and release vegetative propagules; therefore, hand-pulling may spread viable plant parts to adjacent sites or can re-infest the cleared sites if not done carefully. Also, the sediment layer in the Tahoe Keys lagoons could easily be disturbed by hand-pulling resulting in increased turbidity levels.

Hand removal of fragments lodged on shorelines is beneficial in reducing the dispersal of plant propagules. Plant fragments that drift to areas behind docks and piers could be removed by hand from these areas, using rakes or screens, to complement other management actions.

The League to Save Lake Tahoe program Eyes on the Lake trains volunteers to spot and report aquatic weeds and other AIS. Through this program, the League also trains volunteers about how to remove aquatic weeds when they are spotted. Many residents of the Tahoe Keys actively volunteer with the League and participate in the programs that are offered.

3.5 Cultural Controls

Cultural control of weeds refers to techniques that create conditions in which weeds are less likely to become established or are less likely to increase in population size. These techniques include reducing availability of nutrients or preventing nutrient accumulation to impede weed growth.

Reducing available nutrients in the water is very effective for management of nuisance algal blooms, but is less effective on rooted plants. Rooted plants obtain sufficient nutrients from the sediment layer: almost all nitrogen and phosphorous move into the plant tissues via uptake by the roots (Barko 1980).

Aquatic plant senescence plays an important role in nutrient cycling in the aquatic environment. As plants die, 50% of the nutrients are resorbed by the soil particles in the sediment layer and the other half are deposited in the leaf litter and are mineralized in the detritus (Aerts 1996). The sediments in shallow waters like the Tahoe Keys lagoons have high levels of oxygen and the hydrosoil has a high affinity to bind phosphate

Reducing non-point sources of nutrients and observing BMPs for landscape maintenance help keep landscapes visually attractive while reducing nutrient run-off into surface waters. BMPs include minimizing the amount of fertilizer applied to lawns and gardens to the quantity needed for healthy plants and reducing or eliminating phosphorous fertilizer. Reducing overspray and run-off from irrigation keeps the fertilizer in place in the garden and out of the environment and reduces the need to re-apply fertilizer. Choosing plants that have low fertilizer and low water-use requirements also help protect the environment because these plants need fewer resources for a healthy landscape.

Utilizing BMPs can result in decreasing the amount of nutrients entering the water and decreasing the amount of sediment deposition in the water, both of which can help decrease the rate of aquatic plant growth.

Successful cultural control by reducing nutrient inputs is dependent on changed practices from business-as-usual activities. This requires informing and educating the responsible parties so that they can modify their behaviors and approaches. In this respect, education and outreach are essential for cultural control of aquatic plants.

Advantages

- Reducing run-off from fertilized landscapes can be easily achieved through improved irrigation management and other practices such as buffer strips.
- Reducing nutrient inputs via runoff will lessen the likelihood of sustained algal blooms.
- Optimizing the amount of fertilizer applied to the landscape saves money.
- Optimizing irrigation saves water.

Disadvantages

- Reduced nutrient availability is not sufficient to control the growth of invasive aquatic plants.
- Modifying behaviors and entrenched practices can be difficult in certain situations.
- Compliance with BMPs can be difficult to monitor.

Suitability to Tahoe Keys Lagoons

The nuisance aquatic species of the Tahoe Keys lagoons are primarily rooted plants which can derive necessary nutrients from the underlying sediment. With the exception of the native plant, coontail, the primary target nuisance aquatic plants in the Tahoe keys lagoons are rooted plants that rely almost exclusively on nutrients from the sediment.

Developing and utilizing BMPs for the Tahoe Keys lagoons is important to the success of the Plan. Successful implementation of BMPs will reduce the contributions of landscaping maintenance to the problems of aquatic plant growth and will engage and educate the residents of the Tahoe Keys to take measures to reduce the proliferation of aquatic plants in the Tahoe Keys lagoons.

TKPOA has drafted the Nonpoint Source Water Quality Management Plan for the Tahoe Keys Lagoons (NPS Plan) (TKPOA 2016b). The NPS Plan includes BMPs specific for the common areas and the single-family properties in the Tahoe Keys which address irrigation efficiency, fertilizer use, and a monitoring program to demonstrate compliance. Enforcement measures for BMPs on private properties in Tahoe Keys are codified in the Architectural Control Rules Brochure (ACRB), issued by the Architectural Control Committee (ACC) of TKPOA. Violations of the ACC rules result in penalties such as fines or restrictions imposed on the property owner.

Table 4. Summary Table of Approved Methods of Aquatic Invasive Plant Control

Method	Advantages	Disadvantages	Comments
Mechanical Harvesting	• Provides immediate improvement in treated areas • Does not require additional permitting • Some nutrients are removed from the site along with the harvested plant material • Large areas can be treated relatively quickly	• Control is short-term and non-selective • Method generates viable plant fragments that can be transported from the treatment area • Non-target impacts include harming fish • Water turbidity can be temporarily increased	This method will continue to be used in the Tahoe Keys lagoons. Improvements to methods for collecting fragments will continue to be made.

Method	Advantages	Disadvantages	Comments
		• Plants tend to grow back more quickly	
Bottom Barriers	• Direct, immediate control of aquatic plants • Can be used in areas otherwise difficult to treat, such as around piers or docks	• Non-selective control of plants • Non-target organisms affected • Control is temporary • Can be difficult to secure in-place	Useful in small-scale applications. TKPOA has developed a program for homeowners to install bottom barriers and conducted a larger scale test in 2017.
Diver-assisted suction removal	• Can be selective against target species • Majority of plants and plant propagules can be removed from treated area	• Can cause unacceptable increases in turbidity • Diver safety and turbidity curtains can restrict navigation through treatment areas.	Useful in small-scale applications.
Hand-pulling	• Method can greatly reduce regrowth in the treated area. • Can be an effective and comparatively inexpensive method to remove aquatic plants. • Impacts to non-target species, can be minimized.	• Labor-intensive method • Reduced visibility in turbid water can impede removal plants • Suitable in shallow water • Turbidity could increase to unacceptable levels when sediments are disturbed as the plants are pulled from the sediment. • Increased nutrient levels in the water could result if significant amount of decaying plant	The League to Save Lake Tahoe regularly trains volunteers to recognize invasive plants and coordinates volunteer groups to treat shallow water areas of Tahoe Basin

Method	Advantages	Disadvantages	Comments
		material is left behind. • Plant fragments and propagules that are not captured during treatment can drift from the area or can re-infest the treated area.	
Cultural Control through Nutrient Reduction	• Reducing run-off from fertilized landscapes can be easily achieved through improved irrigation management and other practices such as buffer strips. • Reducing nutrient inputs via runoff will lessen the likelihood of sustained algal blooms. • Optimizing the amount of fertilizer applied to the landscape saves money. • Optimizing irrigation saves water.	• Reducing nutrients may not provide sufficient control • Difficult to monitor compliance by individuals	Control through Nutrient Reduction is implemented through the Nonpoint Source Water Quality Management Plan for TKPOA.

4.0 RECOMMENDED PLAN IMPLEMENTATION

This section describes the proposed implementation of the Plan beginning in 2018. The recommended strategy integrates using approved methods of aquatic plant control, making specific improvements to those methods, and provides for focused surveys of aquatic plants and monitoring throughout the Tahoe Keys lagoons.

In 2017, TKPOA further expanded its aquatic plant management program. The Harvesting Program was revised and expanded to better suit the needs of the homeowners while still providing a scientific based approach to aquatic plant control. Education and outreach activities were also improved and expanded in order to more efficiently disseminate information about the IMP. Additionally, in an effort to gain more knowledge about the ecology of the Tahoe Keys Lagoons and the effects of various control methods on the non-native and native plants found in the lagoons, several studies were conducted including a large scale bottom barrier test, regular water quality sampling, sediment sampling, and an herbicide mesocosm study.

This section also describes how the various control methods are evaluated for efficacy using a defined list of performance criteria and how the results will be reported annually to the Lahontan Board.

4.1 Integrated Aquatic Plant Control Methods

The approved methods for aquatic plant control in the Tahoe Keys lagoons are:

- Mechanical harvesting
- The placement of bottom barriers
- Education and Outreach
- Diver-assisted suction

The TKPOA AIS Coordinator is responsible for ensuring that IMP activities are implemented according to plan, making minor, real-time adjustments to control work, assessing control activities and making recommendations for improvements.

Mechanical Harvesting

Mechanical harvesting increases the number of viable plant fragments in the water over background levels and increases the probability of vegetative growth by creating an abundance of long plant fragments with active nodes from which new plants can form (TKPOA 2014b). Starting in 2016, TKPOA made improvements to

equipment and to operations that decreased the potential for aquatic weed fragments to escape and spread and improved operations to increase efficiency. In 2017, TKPOA further improved fragment collection techniques based on the results from the 2016 season.

New Machinery for Fragment Collection

Following the successful results of the 2016 Skimmer Workboat Evaluation (TKPOA 2016a), retrofit of the skimmer boats with fragment collection nets, similar to those described in the 2014 fragment study (TKPOA 2014b), were started in order to collect fragments more effectively. Due to complications with the manufacturing of the nets and decay of the skimmer boats themselves, only one boat was retrofitted. For the 2018 season, it will be vital to the success of the retrofits for the boats themselves to be sound and in proper working order. This may require complete overhauls of the boats or the potential purrochase of new boats.

Based on the results of the 2016 workboat demonstrations and the recommendation of the AIS Coordinator, the OmniCat was purchased for the 2017 season. The OmniCat is a trash/debris skimmer designed for relatively sheltered waters. The vessel, 23' long and 8'3" wide, is manufactured with marine grade aluminum. The draft of the OmniCat is relatively shallow, at 12 inches and one outboard motor can propel the vessel, however, to improve the turning radius, two motors were used.

The OmniCat runs seven days a week collecting fragments from the main navigation lanes of the lagoons. During the 2017 season it collected 430 cubic yards of plant material over the course of four months (TKPOA 2018b). For the 2018 season, the schedule should be reviewed to see if any improvements can be made.

During 2018, TKPOA will also be pursuing installation of a bubble curtain in the West Channel. The idea of the curtain is to create a barrier between the lagoons that will trap the majority of fragments within the channel where they can be easily collected. Also to be installed with the bubble curtain are Seabins. A Seabin is a type of active skimmer that utilizes a pump to draw debris into a large canister which can then be emptied.

Modified Field Operations

In addition to modifying the harvesting machinery, the TKPOA AIS Coordinator will continue to focus on:

- Staff training.
- Directing crews to collect plant fragments that accumulate at boat back-up stations and in dead-end coves.
- Directing crews to focus on surface and near surface fragments instead of deep water plant material.

Bottom Barrier Program

The WDRs issued to TKPOA limit the total amount of acreage that can be covered by bottom barriers in any given season to five acres. The 2017 Bottom Barrier program included individual homeowners and a large scale demonstration.

The results of the program continued to be mixed. Homeowners in the main lagoon experienced sediment buildup and regrowth of plants on top of the barriers while those in the Lake Tallac were able to maintain clear shoreline areas. The large scale demonstration in the Main Lagoon also experience a large amount of sediment buildup which made removal of the barriers more difficult. This indicates that using bottom barriers in densely infested areas with high boat traffic provides limited control of aquatic plants. However, TKPOA will continue to utilize bottom barriers where possible and will continue to use them as part of the overall IMP.

In 2018, TKPOA will continue with the bottom barrier program for single-family property owners that was initiated in 2016 (see below).

The AIS Coordinator will have responsibility for:

- Overseeing installation of bottom barriers at residences
- Weekly monitoring to ensure barriers are still in place and undamaged
- Overseeing removal
- Photo documentation of program
- Data collection to support end of year reporting

Homeowner Installations

TKPOA began the bottom barrier program for homeowners in 2015. The barriers for the program were provided to TKPOA by LTAISCC. To participate in the program, homeowners are required to complete an application to receive a permit from TKPOA for bottom barrier

installation. Homeowners were responsible for placing and removing the bottom barriers in accordance with the terms of the program.

Homeowners provided summaries of their experiences with the program and this information was used to improve the program in 2016. Modifications included:

- Clear instructions in the permit application
- Explicit program guideline for homeowners to follow
- Providing better materials to homeowners to secure barriers
- Allowing homeowners to install more than one barrier on their property

Education, Outreach and Cultural Control

Public outreach is a continuous process that requires multiple types of communications, media and events in order to convey facts about the program and to provide periodic updates on progress in achieving the goals of the Plan.

TKPOA currently has a robust outreach program that educates the membership about Tahoe Keys issues including aquatic plant harvesting, water quality data, and steps that can be taken to reduce nutrient loading of the surface waters of the Tahoe Keys. TKPOA has augmented that program to include:

- Informational brochures for the Tahoe Keys about the IMP and that describe how BMPs can be used at their property.
- Convening workshops on identifying aquatic plants and installing bottom barriers at private properties.
- Providing a means for homeowners and renters to contact TKPOA management about suspected non-native plant infestations.
- Posting information about harvester action and aquatic plant removal on TKPOA's website.

Education and outreach efforts will continue in 2018 with an increased emphasis on BMPs.

Reducing Nutrient Inputs to the Tahoe Keys Lagoons

TKPOA implemented the NPS Plan in 2016 to address both a finding of the WDRs and as an aquatic plant control method in the IMP (TKPOA 2015). The NPS plan directs TKPOA to increase its institutional control, education, and outreach to homeowners, as well as installing BMPs, such as rain gardens, in order to reduce the inputs to the of nitrogen and phosphorus, the pollutants identified in the WDRs as those of primary concern to the surface waters. The

NPS Plan identifies land-based activities in the Tahoe Keys Facility that have the potential to discharge into surface water and act as a source of pollutants and recommends site-specific management practices that can be implemented in order to reduce or prevent this discharge.

Prior to the NPS Plan, TKPOA had implemented the following rules to minimize nutrient run-off into the surface waters of the Tahoe Keys lagoons:

- The use of phosphorous fertilizer in the Tahoe Keys Facility was banned.
- Water Use Restrictions, which specified landscape watering days and times throughout the Tahoe Keys Facility, were instituted by the TKPOA Board.
- The Water Use Restrictions state that water from sprinklers is not allowed to flow over the ground surface onto surfaces that cannot absorb the water.

The NPS Plan includes training for landscape professionals working in the Common Areas of the Tahoe Keys development and training for owners and managers of single-family properties on how to use fertilizers properly and how to manage landscape irrigation systems to prevent run-off. TKPOA will use the NPS Plan to improve the education and outreach program for TKPOA membership and will hold a series of seminars and workshops.

The NPS activities will be reviewed annually by the ACC and WQC through the NPS Adaptive Management Program. Necessary changes will be made to the ACRB to improve compliance or to promote installation of additional BMPs. The result of the evaluation, along with updates and refinements, will be reported to the Lahontan Board. Success of the NPS Plan will be measured by:

- Monitoring compliance by TKPOA staff and landscaping companies with the nutrient reduction rules to reduce fertilizer use and prevent irrigation water runoff.
- Tracking member participation in educational workshops.
- Tracking member participation in TRPA's Stormwater Management Program to obtain certification for BMP installation.

Reducing Fragment Transport by Boat

TKPOA has installed a series of buoys in the Main Lagoon with informational signage instructing boaters to stop, reverse, and dislodge plant fragments attached to their boats before travelling to Lake Tahoe. Observational surveys were conducted during the

course of the boating season and showed that a high percentage of homeowners followed the guidelines while renters and visitors often did not. The boat backup station will be revised again in 2018.

Diver-Assisted Suction Dredging

TKPOA does not plan to use this method in 2018 but it will be considered for future control work. Diver-assisted suction may prove to be useful in areas that do not respond to other control activities.

Monitoring

A consistent and systematic approach to monitoring the populations of invasive aquatic plants is required to determine the efficacy of the treatment methods and is essential to adaptive management. Using established protocols and documenting the locations of the populations of aquatic plants using GPS and Geographic Information System (GIS) ensures that the surveys are consistent year to year and across all treated areas.

TKPOA will also monitor changed conditions after implementation of aquatic plant control methods by evaluating water quality constituents.

TKPOA will summarize the survey and water quality monitoring information in the annual report for review by the Adaptive Management Review Committee and by the Lahontan Board.

Annual Macrophyte Survey

TKPOA will conduct the annual macrophyte survey to determine the presence and coverage of aquatic invasive plants in the Tahoe Keys lagoons. The 2018 survey will follow the protocols established for previous surveys. The results of the 2018 survey will be compared to the results of the prior surveys to examine changes in the aquatic macrophyte populations, and trends in species composition, biovolume, or abundance.

Water Quality Sampling

In 2016, TKPOA collected water quality data on key constituents before and after IMP implementation to assess the impacts the control methods have on environmental conditions. Data collected includes: nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), orthophosphorus, total phosphorus (TP), dissolved oxygen (DO), turbidity, temperature, depth, pH, and Aluminum (Al).

Beginning in April 2017 TKPOA began monthly water quality sampling in all three major water bodies within the Tahoe Keys lagoons, including the Main Lagoon, Marina Lagoon, and Lake Tallac, in addition to sites just outside the Tahoe Keys in Lake Tahoe. The purpose of the water quality sampling was to obtain baseline data on ambient water conditions within the lagoons and to determine the average amount of several nutrients within the water column including phosphorus and nitrogen. Water quality sampling is an essential element of the overall monitoring of conditions in the Tahoe Keys lagoons and the results will provide guidance for updates and adjustments in the IMP.

Sampling continued through October 2017 and the results showed that while the nutrient levels in the Tahoe Keys lagoons were higher than that of Lake Tahoe, they were still detected at relatively low levels that would not be improved by means of filtering through the water treatment plant as has been suggested. It was also found that nutrient levels were similar to that found in the local ground water, suggesting that the plants growing in the water column may not be a significant contributor of nutrients.

For more detail about the 2017 Water Quality Sampling Program and anticipated changes for 2018, please see the final report from TKPOA, *2017 Baseline Water Quality Report for the Tahoe Keys Lagoons* (TKPOA 2018c).

Monitoring will continue in 2018 at selected sampling stations established in 2016. Based on input from stakeholders and regulatory agencies, the 2018 sampling will also include water column profiles of pH, DO, and temperature.

4.2 Planned Research Program

The infestation of aquatic plants in the Tahoe Keys lagoons is a complex problem requiring continued research of new and novel methods of control that are efficacious and suitable to the site conditions of the Tahoe Keys lagoons. For this reason, TKPOA has added Goal 2 to the IMP:

> *To support improvements and updates to the IMP, TKPOA will continue to refine existing methods of aquatic plant control and to research new, safe, cost-effective methods to control aquatic invasive plants. The Adaptive Management Program Committee and the Lahontan Board will objectively evaluate these methods and propose feasible methods for inclusion in updates to the IMP.*

This work will provide necessary information for identifying methods with the potential for achieving desired levels of control. Results of this testing will be part of the Adaptive Management Review of the Plan. New methods showing promise will be considered for inclusion in future updates.

Sediment Sampling

Many aquatic plant control methods disturb the sediment. This disturbance may be inadvertent, such as during hand-pulling or mechanical harvesting, however, disturbed sediment can release unwanted pollutants such as nitrogen or phosphorous into the water column. As such, TKPOA conducted sediment sampling of the Tahoe Keys lagoons during 2016 and again in 2017, in order to determine the possible types and amounts of nutrients or minerals that could be released into the water column as a result of aquatic plant control activities. As with the water quality sampling, locations were recorded by GPS so that sampling is properly replicated in the future.

Sediment sampling in the Tahoe Keys lagoons was conducted twice during 2017, once at the beginning of the growing season and once

at the end of the growing season. This was done in order to determine the baseline level of nutrients within the lagoons and if any significant change in nutrient levels could be seen between early and late season sampling. Like the water quality sampling, sediment samples were taken from all three major bodies of water in the Tahoe Keys, in addition to sites in Lake Tahoe.

The results of the sediment analysis showed that there is a higher percentage of organic matter in the Tahoe Keys than Lake Tahoe and that there are increased levels of aluminum and nutrients. The higher level of aluminum can be attributed to an excess alum water treatment event that occurred in 1998 and the high level of organic matter is likely due to the abundance of aquatic plants within the lagoons that go through seasonal senescence and decay.

For more detail about the 2017 Sediment Sampling Program please see the final report from TKPOA, *2017 Sediment Baseline Report for the Tahoe Keys Lagoons* (TKPOA 2018d).

Monitoring will continue in 2018 at select sampling stations established in 2016. In 2018, sediment sampling may also include measurement of oxidation-reduction (redox) potential as well as sediment cores to determine the depth and composition of the fine sediment layer.

BMI Sampling

BMI sampling is an integral part of water quality assessment programs and important when evaluating the ecological integrity of an aquatic ecosystem. While BMIs tend to remain in their original habitat, freshwater species are highly sensitive to environmental changes (i.e. water quality constituents) allowing their distribution and abundance to be used as an indicator for pollutant loads. Tolerance of such changes in the environment is often species dependent. If water quality is degraded, or degradation is moderate but sustained over time, the community structure may simplify in favor of the more tolerant species. Under these conditions, the abundance of certain species may increase and the diversity, or species richness as measured by the number of different species in a given area, may decrease.

Through the assessment of indicator species populations, diversity, and functional groups of the BMI community, it is possible to determine if the water is impaired for BMIs. The data collected in the BMI Sampling Project is analyzed in the context of data collected for water quality parameters to fully assess the conditions in the Tahoe

Keys lagoons. As with the water quality sampling, locations were recorded by GPS so that sampling is properly replicated in the future.

BMI sampling was conducted once in the summer of 2016. BMIs are often used as an indicator for the health of the ecosystem as a whole because some organisms are more tolerant of disturbance and degraded water quality conditions than others. A higher occurrence of tolerant organisms indicates an impaired waterbody. Sampling in 2016 was conducted to provide set protocols for sampling and a baseline for future years' comparison.

Overall, the species found within the Tahoe Keys lagoons suggest a tolerant community that can withstand impaired water quality. However, without previous comparable data it is not possible to make any conclusions on the increased or decreased health of the lagoons over time. However, the data collected does provide a baseline that can be used to compare future sampling after the implementation of various control methods to determine the control method's effect on the BMI community.

For more detail about the 2016 BMI sampling please see the final report from TKPOA, *Benthic Macroinvertebrate (BMI) 2016 Sampling Report* (TKPOA 2016d).

Rhodamine Water Tracer (WT) Dye Study

Several dye studies were conducted in 2016 to assess the seasonal flow characteristics of water near the West Channel and also to determine the effectiveness of a double barrier system to contain water soluble products.

The studies showed that water does not flow out the West Channel into Lake Tahoe during late spring, and in early summer only flows part way into the channel. This indicates that if a water soluble product such as an herbicide were applied in the late spring, then the likelihood of the product flowing out the West Channel into the lake is very low. In addition, double rows of turbidity curtains were able to contain the dye and when removed the dye travel approximately 1,000 feet even after two weeks of flow during the summer, indicating that water movement in the back channels of the Tahoe Keys Lagoons is very limited.

For more detail about the RWT Dye studies conducted in 2016 please see the final report prepared by Dr. Lars Anderson, *Rhodamine WT Dye Applications in the Tahoe Keys Lagoons* (Anderson 2016).

Herbicide Mesocosm Study

In order to better understand the effects of several different herbicides on the non-native and native aquatic plants found in the Tahoe Keys lagoons, a replicate mesocosm study was conducted using sediment, plants, and water taken from the lagoons. All materials including plants, sediment, and water were kept isolated from the lagoons to prevent any possible contact of herbicide with the waters of the Tahoe Keys Lagoons.

The herbicides used in the study were United States Environmental Protection Agency (EPA)-approved Aquathol K, Renovate, and Galleon. An additional herbicide, Procellacor, was also used, but is still under review by the EPA. Initial results showed that Aquathol K, a contact herbicide, was effective at controlling Eurasian watermilfoil, curlyleaf pondweed, and coontail while elodea continued to grow without adverse effect. Renovate was effective at controlling Eurasian watermilfoil and curlyleaf pondweed, Procellacor controlled Eurasian watermilfoil and curlyleaf pondweed in addition to stunting the growth of coontail. Galleon had limited effects on all plants except for elodea which it had no effect on. This could potentially be due to the low concentration that was used for the study (Anderson 2017).

Research Reports: Rotovating and Weed Rolling, Water Circulation, Biological Control

Alternative mechanical methods to control aquatic plant that have been used at other locations for controlling invasive aquatic weeds found in the Tahoe Keys lagoons include rototilling and weed rolling.

Rototilling or Rotovating

Rotovating describes underwater tillage of aquatic plants typically used in small areas, such as swimming zones with few obstructions and where the primary concern is human safety, rather than preservation of native habitat. Specialized machinery with a rotating, solid tine head is lowered to the bottom of the water column and is used to physically till the sediment to a depth of several inches, dislodging the roots and rhizomes. Much of the plant material floats to the surface where it must be removed by screens and suction systems. These operations typically require temporary installation of turbidity curtains around the treatment area to contain the disturbed silt and to entrap cut plant fragments to prevent infesting the surrounding area.

Rototilling can reduce the biomass of Eurasian watermilfoil by over 80% and the treated area can remain weed-free for a year or more (Dunbar 2009), but can encourage the growth of curlyleaf pondweed, if present, by reducing competition and encouraging the sprouting of turions and seeds which may not be removed with the roots of the aquatic macrophytes.

A plan for rotovating in the Tahoe Keys was initiated in early 2017. However, after consultation with permitting agencies it was determined that the potential for releasing aluminum from the sediment layer into the water column, increasing turbidity, and creating conditions unsuitable for fish, was too high. In order to move forward with the project a detailed environmental review, such as an Environmental Impact Report (EIR), would be needed and still would not guarantee that the project could be conducted.

Weed Rolling

Weed rollers use long metal cylinders attached to a dock or a piling at one end as a motor drives the cylinder to rotate in a 270 degree arc around the attachment point. The aquatic plants and soil are compressed in the treated area. This method can be used in small, high-use areas with no submerged obstructions. The system is usually installed and operated in early spring so that the rotating arm can periodically sweep over newly sprouted plants, thus maintaining a relatively clear area beneath the path of the sweeper

Similarly to Rotovating, topsoil particles are lost when they become suspended in the surrounding water column as the Weed Roller or Bottom Sweeper moves across sediment. This disruption of the upper layers of sediment results in increased turbidity levels as well as the production of viable plant fragments, and disturbs bottom-dwelling organisms or spawning fish (SFEI 2004).

Water Treatment/Circulation System

The treatment system was originally constructed to reduce both total suspended solids and turbidity. The existing water treatment plant consists of a large 117 foot diameter circular clarifier and mechanical building. In 2016 an evaluation of the existing water treatment plant was conducted for nutrient reduction.

Biological Nutrient Reduction (BNR) could be used in the Tahoe Keys with the existing water circulation and treatment plant system. However, the concentration of nutrients present is so low that there would likely be no reasonable improvement following the use of

current BNR technologies. Nitrogen reduction with the water treatment system was dismissed, as phosphorus rather than nitrogen is the limiting agent and therefore not considered a rate limiting agent in the Tahoe Keys lagoons. Furthermore, current methods for reducing nitrogen below existing levels is prohibitively expensive. Turbidity levels seen in the Tahoe Keys lagoons is at or better than the clarifier's original threshold and clarifier reuse would result in no improvement to the expected turbidity levels.

The existing circulation system could also be used to draw cooler water from Lake Tahoe proper into the Tahoe Keys lagoons to displace the warmer water in the lagoons. Reducing the water temperature to 57.2˚F or less may affect the biomass production rate of aquatic macrophytes. In order to cool the lagoon's temperature from 66 °F to 57.2°F about 2,500 tons of cooling would be required. However, this is estimated to be insufficient to provide net cooling of the lagoon due to thermal mixing with the rest of the Lagoon. Given the tremendous capital and operational costs, mechanical cooling was dismissed as a viable engineering control.

The circulation system was also evaluated for its ability to collect suspended aquatic macrophyte fragments as most of the aquatic weeds of concern in the Tahoe Keys lagoons are able to reproduce from the dispersal of viable fragments. The circulation system was determined to have potential for fragment control, especially if paired with screening equipment, and warrants further investigation.

For more details on the 2016 evaluation of TKPOA water treatment/circulation system, please refer to *Draft Treatment Options and Engineering Controls for Aquatic Invasive Plant Mitigation* (ROA 2017).

A subsequent assessment was conducted during 2017 by another engineering firm, Domenichelli & Associates. This assessment focused on rehabilitation of the circulation system and treatment plant. Since the circulation system has been offline for a number of years, the condition of many of the components is unknown and will require further investigation. However, preliminary cost estimates for rehabilitation of the system range from $3.7 to $8.9 million. Due to the high cost and unknown conditions of the system, it will likely take several years to bring the circulation system back online and will not be considered a viable fragment control option during 2018.

For more details about the 2017 assessment of TKPOA water treatment/circulation system, please refer to *Draft Technical Memorandum - Tahoe Keys - Potential Cost v. Benefit and Condition*

Assessment Approach of the Existing Hydraulic Circulation System (D&A 2017).

Dredging and Dewatering

Dredging, the removal of benthic substrate, could reduce the available nutrients for the rooted aquatic invasive weeds curlyleaf pondweed and Eurasian watermilfoil, as much of their nutrients are derived from the sediment to which they are rooted. Dewatering to create a firm surface for dredging equipment to operate on would require the use of an impermeable barrier to block off the West Lagoon and remove water via multiple dewatering wells situated at several locations due to variations in the Lagoon bathymetry.

Three impermeable barriers were evaluated for use in the Tahoe Keys West Channel, including a frozen core dam, water inflatable cofferdam, and an impermeable curtain. The inflatable coffer dam was selected as the best, most cost efficient, and reliable impermeable barrier. If an inflatable coffer dam is used, the level in the Tahoe Keys could be reasonably maintained with no net leakage, even if there are sudden changes in the Lake level from winds.

However, there are several risks associated with this approach. The effect of dewatering, the loss of hydrostatic pressure, followed by the removal of up to a foot of benthic substrate on existing bulkheads and other structures located throughout the Tahoe Keys lagoons has not been thoroughly investigated and could compromise the integrity of existing structures. Furthermore, the amount of groundwater inflow into the Tahoe Keys lagoons would need to be offset by pumping in order to sustain the dewatered level. This would require treatment of pumped waters and disposal of solids and other materials from both the dredging and dewatering.

For more details on the 2016 evaluation of dredging and dewatering, please refer to *Draft Treatment Options and Engineering Controls for Aquatic Invasive Plant Mitigation* (ROA 2017).

Floating Treatment Wetlands

Public comment received on the Draft IWMP in 2015 included investigating the use of Floating Treatment Wetlands (FTW) to help reduce levels of nutrients in the Tahoe Keys lagoons. FTWs are floating mats implanted with hydroponically sustainable plants. FTW are a relatively new method of treatment to reduce both nutrient concentrations and suspended sediment particles in a body of water. Previously, FTW have been used to treat stormwater retention

ponds, municipal wastewater treatment ponds and agricultural and farm lagoons with varying levels of success.

FTW can act as a passive filtration system that is able to remove up to 10,600mg of nitrate per day, 273mg of ammonium per day, and 428mg of phosphate per day (Stewart et. al 2008) when ambient air temperatures are within the optimum growing range. Microbial transformation and uptake by the bacteria and fungi growing along the bottom of the floating mat and plant roots, as well as macrophyte assimilation, act as the primary mode of nutrient removal while suspended roots act to slow water flow and aid in the settling of suspended particles.

The use of FTW may be beneficial in the Tahoe Keys lagoons as multiple studies have shown results illustrating lower nutrient concentrations and total suspended solids in a water body after use. However, it is likely that FTW may be too obtrusive for use in the Main and Marina lagoons of the Tahoe Keys, where there is heavy boat traffic, narrower channels and numerous docks. Temperature conditions in the lagoons are also not optimal for the FTW process. Uptake of nutrients by FTW in South Lake Tahoe would be restricted to between June and August due to temperature and light limitations throughout the season.

Installations of FTW may be possible in Lake Tallac where there are no narrow navigation channels or motorized boats. Since the water flow is limited in Lake Tallac and water quality tends to be poorer than that of the Main and Marian Lagoons, it could potentially benefit more from FTW installations.

This information will be used by the Adaptive Management Review Committee to critically evaluate this technology and its suitability for use in the Tahoe Keys lagoons.

For more details on the 2016 evaluation of floating treatment wetlands, please refer to *Evaluation of Floating Treatment Wetlands for Potential Use in the Tahoe Keys Lagoons* (TKPOA 2016e).

Biological Control

Biological control relies on the use of living organisms to control unwanted aquatic weed growth. There are several biological control methods that have been used to control the growth of aquatic plants. The watermilfoil weevil, *Euhrychiopsis lecontei*, is native to North America and has been reported to feed and reproduce on both native Northern watermilfoil and non-native Eurasian watermilfoil. The

water hyacinth weevil, *Neochetina eichhorniae*, has been used to control populations of water hyacinth. The grass carp fish has been used to control various aquatic plants.

At this time, none of the biological controls included in the alternative methods research are available for utilization in the Tahoe Keys lagoons. The most plausible method is the use of grass carp. However, this method is currently not recommended as grass carp are not native to the Tahoe Basin and have been found to feed on other aquatic plants, including natives, prior to the target plant Eurasian watermilfoil. Because biological control relies on releasing a live organism that is likely to be non-native, there are strict guidelines, both federal and state, and review processes that must be followed before the biological control agent is deemed safe for use. Regulations currently prohibit introductions of biological controls such as grass carp within Lake Tahoe waters.

For more details on the 2016 evaluation of biological controls, please refer to *Biological Control of Aquatic Plants and Potential Use in the Tahoe Keys Lagoons* (TKPOA 2016f).

Future Research and Surveys

In January 2017, TKPOA submitted the Application for Exemption to the Basin Plan Prohibition on the Use of Pesticides for the Tahoe Keys West Lagoon Integrated Control Methods Test to the Lahontan Board and the TRPA. The application was then amended and resubmitted in July 2017, based on comments received from stakeholders and Lahontan Board staff. The proposed program would include specific, non-herbicide integrated methods that are proposed for use after initial herbicide treatment, which would begin in 2018. These methods include: rotovating, bottom barriers, and hand removal, with the possible use of UV light control if such technology proves feasible.

TKPOA will continue to research control methods and to conduct surveys to determine conditions in the Tahoe Keys. Planned research includes investigating the use of Ultraviolet (UV) light, between 190-400nm, which has previously been found to penetrate water up to several decimeters. UV-B radiation (280-320 nm) is considered the most harmful of the UV spectrum and can lead to photochemical damage, damage to DNA, damaged cellular and pigment proteins in aquatic macrophytes. UV-B radiation can also reduce the survival rates of pathogenic microbes through chemical conversion of some organics to toxic byproducts. Most often plant exposure to and absorption of UV wavelengths is linked to alterations

of growth rates. TKPOA supports additional research and evaluation of this method and is monitoring the progress of tests conducted by TRCD in 2017.

Additional surveys that could be conducted in the future include waterfowl and other wildlife observations to provide an indication of what species may be affected by control measures and more information on the overall ecology of the Tahoe Keys. The Adaptive Management Review Committee will evaluate the need to conduct additional surveys and provide direction for updates to the IMP.

4.3 Adaptive Management Review Program

(Photo Courtesy of Hypeit, Inc.)

The IMP will provide the managers of the Tahoe Keys lagoons and the residents of the Tahoe Keys an increasingly clearer strategy to control aquatic plants into the future. Priorities for control must remain flexible to adapt to changing conditions to fulfill the Goals and Objectives of the Plan. This section describes the criteria that will be used to objectively evaluate the efficacy and suitability of the range of IMP activities and how updates to the IMP will be proposed by TKPOA for approval by the Lahontan Board.

Membership in the Adaptive Management Review Committee

An Adaptive Management Review Committee will be established to review the annual results of the control methods being used in the

Tahoe Keys lagoons. The responsibilities of the Adaptive Management Review Committee will be to:

- Review plant survey information and data reports generated as part of the IMP to track aquatic plant control success, including the success measurement criteria.
- Assess the compatibility of the control methods with the normal recreational activities of the Tahoe Keys lagoons.
- Make recommendations to improve and update the IMP.
- Evaluate how the Goals and Objectives of the IMP are being met.
- Act as spokespeople to explain the control work to the residents and other interested members of the public

The Adaptive Management Review Committee will be composed of:

- Two experts in the field of aquatic plant management
- Two members from the WQC, who will serve as the liaison between the two committees
- The TKPOA General Manager or AIS Coordinator
- Two members from regulatory or resource agencies in the Tahoe Basin familiar with aquatic weed control activities, such as members of the Nearshore Aquatic Weed Working Group, which is a subgroup of the Lake Tahoe AIS Coordinating Committee

The Adaptive Management Review Committee will meet twice each year: in the first quarter of each year, the Committee will set priorities for the coming year; in the final quarter of each year, the Committee will review the reports and data collected as part of the IMP activities. The Committee will discuss improvements to the IMP and summarize changes to be included in the annual (January submittal) updates of the IMP to the Lahontan Board. The TKPOA General Manager, or his designee, will be responsible for presenting the updates to the Lahontan Board regarding the recommended improvements to the IMP.

Success Criteria

Success Criteria have been selected to measure progress in gaining control of the invasive aquatic weeds in the Tahoe Keys lagoons. Setting numeric targets for success of control activities is very difficult to do for integrated management plans for aquatic plants. There are many unknowns and forces majeure that can affect the success of control activities, including changes in seasonal weather conditions, equipment malfunctions, or unseen impacts.

This IMP addresses three target species, Eurasian watermilfoil, curlyleaf pondweed, and coontail that have reached nuisance levels in the Tahoe Keys lagoons. Depending on location, coverage, and density, each plant may respond differently to the control method applied.

When considering success criteria, it is important to consider that this IMP is to bring the invasive plants under control and improve and maintain recreational and beneficial uses of the waters of the Tahoe Keys lagoons. Also important is that these aquatic weeds are long-standing and TKPOA has consistently worked to manage aquatic plants for well over 30 years.

TKPOA has established standards as Success Criteria for evaluating aquatic plant control methods with realistic benchmarks. The results of the aquatic plant control work will be evaluated annually and standards and benchmarks may be modified depending on the outcome of the control activities. The Success Criteria may need to be applied in a different manner for different control methods. For example, a bottom barrier may be able to completely eliminate aquatic weeds from the treatment area whereas a mechanical harvester could not, however, that determination should not preclude the continued use of the mechanical harvester.

The long-term criteria and goals are focused on bringing the invasive plants under control:

1. Reducing the biovolume of target plants by 90% from 2016 levels by 2020
2. Maintaining sufficient VHC (Distance between top of plant canopy and bottom of the vessel)
3. Reporting increases in the diversity of aquatic plant species present in the Tahoe Keys lagoons during the annual survey
4. Reducing production of fragments from aquatic weed control activities
5. Achieving low levels of non-target effects

Reducing the Biovolume of Target Plants

Invasive aquatic plant biovolume relates directly to the potential for weed dispersal and the likely impairment of beneficial uses of the Tahoe Keys lagoons. The larger the volume of invasive plants present, the greater the potential for the habitat to be more suitable for non-native fish and the greater the likelihood of plant propagules being transported out of the lagoons.

Measuring the biovolume of aquatic plants using hydroacoustic technology is the most current method available to assess levels of

infestations. These measurements were first taken in the Tahoe Keys lagoons in 2015 and are an essential measure for future aquatic plant surveys.
The long-term target goal for biovolume is a reduction of 90% from 2015 levels by the year 2020.

Maintaining Sufficient Vessel Hull Clearance

VHC is a measure of the distance between the tallest plants and the water surface and will be determined using hydroacoustic sampling methods. If the weed height is kept below the hull of vessels in the lagoons, then rooted weeds cannot become entrapped on the boats and be transported elsewhere.

VHC is also a measure of safety for water contact recreation. Most recreational activities, including kayaking, and paddle boarding, occur at the surface of the water. Maintaining clearance along the surface will allow these activities to be practiced more safely.

The performance metric for VHC will be 4 to 6 feet below water surface, and is site-specific, depending upon location and boat traffic.

Reported Increases in the Diversity of Aquatic Plant Species Present in the Tahoe Keys Lagoons during the Annual Survey

The annual surveys of aquatic plants present in the Tahoe Keys lagoons will confirm the species types and composition of the aquatic plant populations and specific locations as verified by point plant samples and using GPS data. This information will allow TKPOA to select precise plant control methods targeted to the aquatic weeds present. Determining the types of plants present will indicate if native plants are increasing as a percentage of the total aquatic plant population and thus an improvement in habitat for native fish and other organisms.

It is not possible to set a numeric target for this criterion, as the percentage and location-specific make-up of natives to non-natives in the Tahoe Keys lagoons has not yet been critically evaluated. Species diversity will be qualitatively determined from the data collected during the annual aquatic plant survey.

Reduced Production of Fragments from Aquatic Weed Control Activities

Aquatic plant fragments have the potential to move and become established in other locations within the Tahoe Keys lagoons and Lake Tahoe. Increased fragments can expand the growth of aquatic

plants. Fragment production from mechanical harvesters was found to be substantial as reported in a 2014 study (TKPOA 2014b).
It is difficult, if not impossible, to establish a meaningful numeric target for reduction of fragment production. Instead, the Adaptive Management Review Committee will look for downward trends reported in follow-up fragment surveys.

Achieving Low Levels of Non-target Effects

Aquatic plant control methods should have minimal impact to non-target organisms, such as native fish, native plants other than coontail, and BMI. Fish and other organisms that may be harmed by IMP activities will be noted in annual reports, and BMI populations will be assessed after IMP activities to compare to baseline data collected in 2016.

Summary

Success Criteria selected for effective invasive aquatic plant control activities are summarized in Table 5. The rationale for selecting these criteria is that current TKPOA aquatic weed management operations are:

- Failing to reduce the volume of invasive aquatic plants such that recreational and other beneficial uses of the Tahoe Keys lagoons are increasingly impaired.
- Failing to reduce aquatic plant fragments that have the potential to disperse to other locations within the Tahoe Keys lagoons and to Lake Tahoe thus introducing new populations of aquatic plants.
- Leaving areas that are difficult to reach untreated, such as areas behind docks and piers. These unmanaged and uncontrolled areas serve as refuge for non-native fish and provide sources of re-infestation through growth and production of plant fragments.

The Success Criteria are based on the projection that integrating all approved methods will maintain VHC for safe navigation and beneficial recreation uses in the Tahoe Keys lagoons, improve habitat for native species, minimize the spread of aquatic plant fragments, and reduce impacts to non-target organisms. The current expectations for achieving the success criteria as a percentage of the area treated by control method are summarized in Table 5. For example, with improved Mechanical Harvesting and Fragment Capture, TKPOA anticipates that in 20% of the area treated, there will be a reduction in biovolume of target plants of 50%, that the required VHC will be met in 10% of treated area, and that there will be no adverse non-target effects in 70% of the treated area. The

expected levels of success are based on currently approved methods.

Table 5. Summary of Expected Success Criteria

	Control Method	Improved Mechanical Harvesting and Fragment Capture	Bottom Barrier Installation
1	Biovolume of target plants reduced 90%	20%	5%
2	VHC sustained June to October	10%	60%
3	Measureable increase in native plants as percentage of all aquatic plants	10%	50%
4	Reduction in fragment production	5%	70%
5	Low levels of adverse non-target effects	70%	70%

Table 6 shows how the success criteria and other monitoring measures will meet the Goal and Objectives for the Plan.

Table 6. Objectives, Monitoring Measures and Success Criteria

Objective	Monitoring Parameters	Success Criteria
Eliminate spreading of AIS from the Tahoe Keys to greater Lake Tahoe.	•VHC •Biovolume	•VHC sustained May-September •Biovolume reduced by 90%
Enhance the overall water quality of the Tahoe Keys lagoons and Keys Marina thereby improving Lake Tahoe water quality and associated clarity.	•Implementing NPS Plan •Water quality testing and testing turbidity levels	•TKPOA membership compliance with NPS Plan •Attainment of Lahontan Board Water Quality Objectives •Maintaining turbidity at permitted levels
Reduce habitat for non-native fish and enhance habitat for native fish in the Tahoe Keys lagoons and Keys Marina.	•Species composition •VHC	•Increased ratio of native to non-native plants. •VHC sustained May-September
Restore and maintain established beneficial recreational uses, including water contact safety in the Keys lagoons and commercial uses in the Keys Marina.	•VHC •Biovolume •GIS-based maps of infestations •GIS-based maps of control work •Maintenance costs	•VHC sustained May-September •Biovolume reduced by 90% •Maps of real-time conditions and maintenance activities available to Tahoe Keys residents.
Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants.	•Reporting to Adaptive Management Review Committee •Continued research for novel aquatic plant control methods	•VHC sustained May-September •New methods evaluated annually.

5.0 SUMMARY: HOW IMP MEETS GOALS AND OBJECTIVES

(Photo Courtesy of Community Ink)

Critical to this Plan is utilization of the most current and effective technology for quantitatively monitoring nuisance aquatic plant populations, namely hydroacoustic sampling, for focused surveys of current conditions in the Tahoe Keys lagoons. In addition to hydroacoustic sampling, other water quality parameters such as dissolved oxygen, levels of nitrogen and phosphorous, and pH will be measured. Summary reports to the Adaptive Management Review Committee will allow TKPOA to detect changes and improvements toward meeting Water Quality Objectives established by the Lahontan Board.

5.1 Goal 1 and Specific Objectives of the WDRs:

The Waste Discharge Requirements issued to the Tahoe Keys Property Owners Association directed TKPOA to develop an Integrated Management Plant for Aquatic Weeds and named objectives to be met under the IMP.

> Objective 1. Eliminate spreading of AIS from the Tahoe Keys to greater Lake Tahoe.

Completely stopping the spread of aquatic invasive plants and other AIS from the Tahoe Keys to Lake Tahoe is likely not possible. Meeting this objective will require not only the diligence of TKPOA to control the growth of aquatic plants but also close coordination

among the resource agencies charged with AIS control, cooperation from the general public and rigorous enforcement of rules and regulations that prevent AIS proliferation. The Lake Tahoe AIS Coordination Committee, TRPA, TRCD, CDFW, and other agencies have already made great strides in this area by implementing a boat inspection and cleaning program and undertaking control programs at locations around Lake Tahoe, its tributaries, and the Truckee River.

TKPOA has been directed by the Lahontan Board to develop the IMP to control the spread of one type of AIS, aquatic invasive weeds, from the areas under control of TKPOA and members of the Association. TKPOA is committed to helping solve the regional problem of the proliferation of aquatic invasive plants, a problem which threatens the water quality and the aesthetics of Lake Tahoe. This IMP describes how proven methods can be integrated to control aquatic plants found in many areas throughout the Tahoe Keys lagoons. This integrated approach provides the best opportunity to protect and enhance the waters of the Tahoe Keys lagoons.

Complete elimination of the spread of AIS from the Tahoe Keys into Lake Tahoe will require complete and permanent eradication of AIS from the Tahoe Keys. A reduction in the potential for plant spread will be accomplished first by reducing aquatic plant biomass and fragment formation with the activities described in the IMP.

The primary goal of all control methods is to reduce weed biomass. As the quantity of source material is diminished, so is the potential for weed spread. Success towards this goal will be demonstrated by surveying the plant population.

The most common weed dispersal bodies are fragments of the parent plants. The majority of fragment production occurs near the surface, where recreational, commercial, and natural activities disturb the weed canopy. Boat propellers, especially, can rapidly generate large quantities of fragments if weed heights reach the water's surface. Harvesting the upper weed canopy will prevent propeller impacts from generating fragments.

Boat propellers are especially culpable in the spread of weeds since they generate fragments and then disperse fragments that have become entangled. Fragment dispersal occurs spontaneously, as buoyant fragments can become detached from plants and transported out of the Keys by wave action. Additionally, harvesting weeds generates fragments. The IMP accounts for this third aspect of weed spread by implementing a weed fragment collection system.

Advances in weed spread prevention need to be incorporated into the IMP. New techniques and technology will be researched and tested to determine if better methods are available. These include requiring boats to back-up in a specified location so entangled weeds can be dislodged and collected, including aquatic plants on the inspection list for the Tahoe Clean Boating Program, and improved skimmer design.

> Objective 2. Enhance the overall water quality of the Tahoe Keys lagoons and Keys Marina thereby improving Lake Tahoe water quality and associated clarity.

Implementation of the IMP will enhance the water quality of the Tahoe Keys lagoons by controlling aquatic plant growth and thereby reducing nutrient concentrations. Aquatic macrophytes and algae form the basis of waterbody productivity, which can be thought of as the foundation of the aquatic food chain: herbivores consume the aquatic plants and algae, foragers consume these herbivores, and so on up the productivity ladder. By effectively controlling the growth of aquatic macrophytes, the overall productivity of the lagoons can be reduced and the associated water quality can be improved.

The IMP describes cultural controls to reduce further input of the nutrients to the waters of the Tahoe Keys lagoons. These controls, also referred to as Best Management Practices (BMPs), are described in full detail in the Non-point Source Water Quality Management Plan (NPS Plan) for the Tahoe Keys, a second plan that TKPOA has written to address the findings of the WDRs (TKPOA 2017). TKPOA plans to implement the NPS Plan in 2018 with activities to reduce fertilizer use and reduce irrigation run-off from landscaped areas and to educate TKPOA members and landscaping professionals working in the Tahoe Keys about the importance of reducing non-point sources of nutrient pollution. The research and demonstration of novel and effective aquatic plant control methods that are suitable to the conditions of the Tahoe Keys lagoons will enable TKPOA to refine and improve the IMP in the future. The research program will identify and evaluate control measures that do not increase turbidity or cause other degradations of water quality.

> Objective 3. Reduce habitat for non-native fish and enhance habitat for native fish in the Tahoe Keys lagoons and Keys Marina.

The IMP was written to control the proliferation of aquatic invasive plants. Two of these plants, Eurasian watermilfoil and curlyleaf pondweed, do not support native fish, and the dense coverage of the aquatic plant canopy in the Tahoe Keys lagoons provides cover for

non-native warm water fish that prey on the fishes native to Lake Tahoe. By reducing the biovolume and canopy cover provided by aquatic macrophytes, habitat for native fish is enhanced.

> Objective 4. Restore and maintain established beneficial recreational uses, including water contact safety in the Keys lagoons and commercial uses in the Keys Marina.

The primary recreational use of the Tahoe Keys lagoons is boating, which occurs at or near the surface of the water. Boat navigation of the waters is facilitated by harvesting the top of the aquatic plant canopy. Recreational activities such as swimming and diving are prohibited in the Tahoe Keys lagoons in the by-laws of the association.

TKPOA retains direct control of maintenance of the Common Areas of the development and has authority to enforce the rules that are adopted by TKPOA Board and published in the ACRB.

TKPOA confers with the surrounding landowners, however, these entities, including the Keys Marina, are not subject to the rules or inforecement actions of TKPOA. control measures implemented by TKPOA in the Marina Lagoon will potentially benefit the surrounding area. However, full recreational, commercial, and beneficial uses of the lagoons can only be restored when all parties of interest implement effective aquatic plant control methods.

> Objective 5. Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants.

In 2018, TKPOA will rely on the approved methods of aquatic plant control. Improvements will be made where feasible in regard to mechanical harvesting and collecting plant fragments generated by the harvesters. Additional approved control methods will be included in the future as funding is available.

5.2 Goal 2 and Objectives

Thoroughly researching additional methods of aquatic plant control will assist the Adaptive Management Review Committee in identifying new methods for consideration in the IMP for field trials and demonstration projects in the near future. Mesocosm and pilot studies will allow for evaluation of new methods for efficacy in the site-specific conditions of the Tahoe Keys lagoons.

Goal 2 states:

To support improvements and updates to the IMP, TKPOA will continue to refine existing methods of aquatic plant control and to research new, safe, cost-effective methods to control aquatic invasive plants. The Adaptive Management Program Committee and the Lahontan Board will objectively evaluate these methods and propose feasible methods for inclusion in updates to the IMP.

In order to fully meet this Goal, superior control measures must be identified and approved for implementation. After research, review, and testing, promising new measures will be introduced to the Lahontan Board for inclusion in subsequent updates of the IMP and the WDRs. TKPOA may be required to acquire additional permits for use of a new or novel method prior to implementing that method under the IMP. TKPOA will continue to work with resource agencies for input and to determine permit conditions. Goal 2 is supported by three objectives:

> Objective 1: Identify and confirm safety and efficacy of proven novel aquatic invasive plant control methods by reviewing scientific literature and reports of these methods used under real world conditions.

To complete this objective, TKPOA will undertake technical review of a variety of additional control measures, some of which have demonstrated efficacy and some of which are new and novel. Once these control measures have been thoroughly reviewed, the Adaptive Management Review Committee will consider them for testing at small-scale level.

> Objective 2: Conduct and monitor small-scale demonstrations of control methods in defined areas of the Tahoe Keys lagoons or in mesocosm studies that mimic the site-specific conditions of the Tahoe Keys lagoons.

These small-scale demonstrations will be scheduled after thorough research is conducted as described in Objective 1, above. These demonstration tests will be conducted under the appropriate authorization of and permits issued by the Lahontan Board.

5.3 Conclusions

TKPOA is taking a comprehensive approach to aquatic weed control. Input has been gathered from experts in the fields of aquatic biology and weed control, from regional stakeholders, and interested

members of the public. Comments and recommendations continue to be received and thoroughly considered in the development of and updates to the IMP.

In 2018, TKPOA will continue to undertake an extensive research and testing program on new, innovative, and combined methods of aquatic weed control. The research program will investigate many of the alternative control methods suggested by the public. The Adaptive Management Review Committee will review the results of the research and testing and objectively evaluate the control methods using established success criteria. The Adaptive Management Review Committee will recommend those methods meeting the criteria for inclusion in updates to the IMP will direct future research projects.

The members of the WQC and TKPOA Board express their deep appreciation to those who have devoted time and energy to the development of the IMP by providing their comments and insights.

6.0 REFERENCES AND LITERATURE CITED

Aerts 1996. Aerts, R. Nutrient resorption from senescing leaves of perennials: are there general patterns?. *Journal of Ecology*, pp.597-608.

Anderson 1996. Anderson, L., and D. F. Spencer. Survey of Lake Tahoe for presence of Eurasian watermilfoil: USDA Agricultural Research Service Aquatic Weed Control Investigations, Annual Report. Davis, CA. 1996.

Anderson 2003. Anderson, L. W. J. A review of aquatic weed biology and management research conducted by the United States Department of Agriculture - Agricultural Research Service. Pest Management Science 59: 801–813. 2003.

Anderson 2005. Anderson, L.W., Tan, and C. Mallek. Preliminary evaluation of SolarBee effects on water quality at Lake Tahoe. Western Aquatic Plant Management Society. 24th Annual Western Aquatic Plant Management Society Meeting, Denver, CO. 2005.

Anderson 2011a. Anderson L.W.J. Use of Rhodamine WT as Surrogate for Herbicide Transport in the Tahoe Keys. Final Report to the Lahontan Regional Water Quality Control Board, Project No. R6T-2010-0037. 2011.

Anderson 2011b. Anderson, L.W.J. Freshwater Plant and Seaweeds. *In* Encyclopedia of Biological Invasions. Daniel Simberloff, Marcel Rejmánek (Editors). 2011.

Anderson 2016. Anderson, L.W.J. Tahoe Keys Rhodamine WT Dye Dissipation and Movement Study: Report to the Lahontan Board. Pursuant to Board Order No. R6T-2010-0037. 2016.

Anglestein 2008. Anglestein, Susanne, and Hendrik Schubert. Elodea Nuttallii: Uptake, Translocation and Release of Phosphorus. Aquatic Biology, Vol. 3. 209-216.

AOU 1998. Check-list of North American Birds. 7th Edition. American Ornithologists' Union, Washington, D.C. 1998.

Baily 2008. Baily, J. E. and A.J K. Calhoun. 2008. Comparison of three physical management techniques for controlling variable –leaf milfoil in Maine lakes. J. Aquat. Plant Manage. 46:163-167. 2008.

Barko 1980. Barko, J.W. and R.M. Smart. Mobilization of sediment phosphorous by Submersed Freshwater Macrophytes. Freshwater Biology, Vol. 10, Issue 3. June 1980.

Barr 2013. Barr, T.C., Integrative control of curlyleaf pondweed propagules employing benthic bottom barriers: Physical, chemical and thermal approaches. PhD dissertation. University of California, Davis, Davis, CA. 2013.

Barr 2014. Barr, T.C. and J. M. DiTomaso. Curlyleaf pondweed (Potamogeton crispus) turion control with acetic acid and benthic barriers. J. Aquat. Plant Manage. 52:31-38. 2014.

Barr 2015. Barr, T C., III and J. M. DiTomaso. Integrating hot water under a benthic barrier for curlyleaf pondweed turion control. J. Aquat. Plant Manage. 53: 1-6. 2015.

Barrat-Segretain 2000. Barrat-Segretain, M.-H., Bornette, G., Regeneration and colonization abilities of aquatic plant fragments: effect of disturbance seasonality. Hydrobiologia 421, 31–39. 2000.

Brockett 2013. Brockett, J., K. Boyd, D. Shaw, and P. Stone. Invasive Aquatic Weed Control Program Lake Tahoe, CA: Bureau of Reclamation Final Report No. R10AP20613. 2013.

Bugbee 2015. Bugbee, G. J., J. A. Gobbons and M. June-Wells. Efficacy of single and consecutive early-season Diquat treatments on curlyleaf pondweed and associated aquatic macrophytes. J. Aquatic. Plant Manage. 53: 171-177. 2015.

Bultemeier 2015. Bultemeier, B. W. and W. T. Haller. Endothall, triclopyr and fluridone granular release profile under static and aerated water conditions. J. Aquatic. Plant Manage. 53:197-201. 2015.

Cao 2015. Cao, Qian-Jin and L. Wang. Effects of silt-laden water on the growth of submerged plants. J. Aquatic. Plant Manage. 53: 202-208.

CDBW 2011. California Division of Boating and Waterways. *Egeria densa* control program Annual Report. 35 p. (with appendices). http://www.dbw.ca.gov/PDF/Reports/EDCP-2011_Annual_Report.pdf

CDBW 2016. California Division of Boating and Waterways Annual Reports. http://www.dbw.ca.gov/Reports/Default.aspx#AIS

CDFW 2014. RAREFIND-5. Query of the California Natural Diversity Database maintained by the California Department of Fish and Wildlife, Sacramento, CA.

Chandra 2009. Chandra, S., Ngai, K. L. C., Kamerath, M., A. Brant. 2009. Warm-Water Non-Native Fishes in Lake Tahoe. Prepared for Nevada Division of State Lands. February 2009. Prepared by University of Nevada, Reno – Aquatic Ecosystems Analysis Laboratory and University of California, Davis – Tahoe Environmental Research Center.

Chandra 2010. Chandra, S., Allen, B., and M. Wittmann. 2010. Ecological Changes in Lake Tahoe: The Influence of Introduced Species.

Chetek 2012. The 2012-2017 Aquatic Plant Management Plant for the Chetek Lakes, Barron County, WI. Prepared for the Chetek Lakes Protection Assoc., Chetek, WI. 2012.

Craig 1998. Craig, D. and P. L. Williams. 1998. Willow Flycatcher (Empidonax traillii). In The Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/htmldocs/riparian_v-2.html

Crowell 1994. Crowell, W., N. Troelstrup, L. Queen, and J. Perry. Effect of harvesting on plant communities dominated by Eurasian watermilfoil in Lake Minnetonka, MN. Journal of Aquatic Plant Management 32:56–60. 1994.

Cuda 2009. Cuda J.P. Chapter 8: Introduction Biological Control of Aquatic Weeds, pp. 47- 53. In: Biology and Control of Aquatic Plants: A Best Management Practices Handbook. Gettys, LA, WT Haller and M. Bellaud, eds. Aquatic Ecosystem Restoration Foundation, Marietta GA. 210 pages.

DiTomaso 2003. DiTomaso, J. M., and E. A. Healy. Aquatic and Riparian Weeds of the West. Regents of the University of California Division of Agriculture and Natural Resources, Publication 3421. 2003.

DiTomaso 2013. DiTomaso, J.M., G.B. Kyser et al. *Weed Control in Natural Areas in the Western United States*. Weed Research and Information Center, University of California. 2013.

DRI 2011. Huntington, J.L., and D. McEvoy. Climatological Estimates of Open Water Evaporation from Selected Truckee and Carson River Basin Water Bodies, California and Nevada. Prepared by the Division of Hydrologic Sciences, Desert Research Institute, Reno, NV. August 2011.

DuVall 2001. DuVall, R.J., et al. Control of Eurasian Watermilfoil in Mesocosms at Lake Tahoe. Proceedings of the California Weed Science Society. 2001.

Eiswerth 2000. Eiswerth M. E., S. G. Donaldson, and W. S. Johnson. 2000. Potential Environmental Impacts and Economic Damages of Eurasian Watermilfoil (Myriophyllum spicatum) in Western Nevada and Northeastern California. Weed Science Society of America 14:511–518.

Fennimore 2014. Fennimore, S., and C. Bell. Principles of Weed Control 4th Edition. California Weed Science Society. 2014.

Frantz and Cordone 1970. Frantz, T.C., and A. J. Cordone. 1970. Food of Lake Trout in Lake Tahoe. California Fish and Game 56:21-35.

Getsinger 1997. Getsinger, K.D. and M.D. Netherland. Herbicide concentration exposure time requirements for controlling submersed aquatic plants: Summary of research accomplishments. MP A-97-2. US Army Engineer Waterways Experiment Station, Vicksburg, MS. 1997.

Getsinger 1997. Getsinger, K. D., et al. "Restoring native vegetation in a Eurasian water milfoil-dominated plant community using the herbicide triclopyr." *Regulated Rivers: Research & Management* 13: 357-375.

Getsinger 2014. Getsinger, K.D., et al. Benefits of Controlling Nuisance Aquatic Plants and Algae in the United States. CAST Commentary July 2014.

Gettys 1997. Gettys, L., W.T. Haller, and M. Belaud. Biology and Control of Aquatic Plants; A Best Management Practices Handbook. Aquatic Ecosystem Restoration Foundation, 3272 Sherman Ridge Rd., Marietta, GA 30064. 2009. http://www.tahoefund.org/about-tahoe/recreational-paradise/ Journal of Aquatic Plant Management. 35: 69-73. 1997.

Gillies 2006. Minute Item C50: Completion of a previously approved demonstration project for hand removal of a non-native invasive aquatic plant, Eurasian watermilfoil, from Emerald Bay, Lake Tahoe and Initiate another small pilot study using a barrier control technique. California State Lands Commission, Sacramento, CA.

Greenfield 2004. David, N., B.K. Greenfield, and G.S. Siemering. Evaluating Impacts of Lake Maid™ Plant Control. J. Aquat. Plant Manage. 44, pp. 60-66.

La Plante 2008. Exchange Flows between the Tahoe Keys Embayments and Lake Tahoe, California-Nevada. A.C. La Plant, MS Thesis, UC Davis. 2008.

LRWQCB 2014. Board Order, No. R6T-2014-0059. California Regional Water Quality Control Board Lahontan Region Water Quality Certification and Waste Discharge Requirements for Tahoe Keys Property Owners Association. July 2014.

Lembi 2009. Lembi C.A. Chapter 12, “The Biology and Management of Algae.” Pp. 79-85 in Biology and Control of Aquatic Plants: A Best Management Handbook, L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA.

Johnson 2012. Johnson, J. A., A. R. Jones, and R. M. Newman. Evaluation of lakewide, early season herbicide treatments for controlling invasive curlyleaf pondweed (Potamogeton crispus) in Minnesota lakes. Lake and Reservoir Management 28: 346–363. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/07438141.2012.744782.

Johnstone 1985. Johnstone, I.M., B.T. Coffey, and C. Howard-Williams. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. Journal of Environmental Management 20:263-279.

Madsen 1999. Madsen J. 1999. Point Intercept and Line Intercept Methods for Aquatic Plant Management. Aquatic Plant Control Technical Note MI-02 February, 1999.

Miller 1951. Miller, R.G. The Natural History of Lake Tahoe Fishes [thesis]. Stanford University, Palo Alto, CA. 1951.

Netherland 2009. Netherland, M. Chapter 11: Chemical control of Aquatic Weeds. In: Biology and control of aquatic plants: A Best Management Practices Handbook. Gettys LA, WT Haller and M Bellaud, eds. Aquatic Ecosystem Restoration Foundation, Marietta GA. 2009.

Netherland 2014. Netherland, M. D. and L. M. Glomski. Mesocosm evaluation of triclopyr on Eurasian watermilfoil and three native submersed species: The role of treatment timing and herbicide exposure. J. Aquat. Plant Manage. 52: 57-64. 2014.

New Hampshire 2008. Report of the New Hampshire Exotic Aquatic Species Program, 2006-2008. Prepared for the New Hampshire Dept. of Environmental Services. 2008.

Newroth 1979. Newroth, P. R. British Columbia aquatic plant management program. J. Aquat. Plant Manage. 17: 12-19. 1979.

Ngai 2014. Ngai, K. L. C. 2014. Non-Native Warmwater Fish Pilot Control Project. Prepared for Tahoe Regional Planning Agency and U.S. Fish and Wildlife Service. November 2014. Prepared by University of Nevada, Reno – Aquatic Ecosystems Analysis Laboratory.

Puyallup 2015. Clarks Creek Elodea Management Program, 2015 Project report. City of Puyallup, Washington. Available at the city website: http://www.cityofpuyallup.org/services/public-works/stormwater-management/projects/clarks-creek-elodea-removal/

Pavlik 2002. Pavlik, B. et al. Conservation Strategy for Tahoe Yellow Cress (Rorippa subumbellata). Tahoe Regional Planning Agency. Lake Tahoe, NV. 2002.

Peterson 1986. Peterson, Allen. Habitat suitability index models: bald eagle (breeding season). Biol. Rep. 82 (10.126). Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 1986.

Poovey 2002. Poovey, A., J. G. Skogerboe, and C. S. Owens. Spring treatments of diquat and endothall for curlyleaf pondweed control. Journal of Aquatic Plant Management 40 :63–67. 2002.

Radomski 2015. Radomski, P, and B. V. Holbrook. A comparison of two hydroacoustic method for estimating submerged macrophyte

distribution and abundance: A cautionary note. J. Aquatic. Plant Management 53: 151-159. 2015.

Rejmánek 2002. Rejmánek, M., and M. J. Pitcairn. When is eradication of exotic pest plants a realistic goal. 2002.

ROA 2017. Draft Treatment Options andEngineering Controls for Aquatic Invasive Plant Mitigation. Prepared for Tahoe Keys Property Owners Association. Prepared by RO Anderson Engineering, Inc. January 2017.

Schladow 2014. Schladow, S. G., A. Hoyer, F. Rueda, and M. Anderson. Lake Tahoe Flow Modeling Potential Pathogen Transport, and Risk Modeling. 2014.

Sculthorpe 1967. Sculthorpe C.D. The Biology of Aquatic Vascular Plants. Edward Arnold (London).1967.

SFEI 2004. Aquatic Pesticide Monitoring Program: Review of Alternative Aquatic Pest Control Methods for California Waters. Greenfield, B.K., N. David, J. Hunt, M. Wittman, G. Siemering, authors

Smith 1990. Smith, C.S. and J.W. Barko. Ecology of Eurasian watermilfoil. Journal of Aquatic Plant Management, 28(2), pp. 55-64.

Snyder 1993. Snyder, S. A. Haliaeetus leucocephalus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). 1993. Available at: http://www.fs.fed.us/database/feis/

Søndergaard 2003. Søndergaard, M., J.P Jensen, and E. Jeppesen. Role of Sediment an Internal Loading of Phosphorus in Shallow Lakes. Hydrobiologia, 506(1-3), pp. 135-145.

Stuckey 1979. Stuckey, R.L. Distributional history of *Potamogeton crispus* (curly pondweed) in North America. Bartonia 46: 22-42. 1979.

TERC 2014. Tahoe Environmental Research Center. Fish Species of Lake Tahoe. Retrieved on January 12, 2015. Last updated October 23, 2014. http://terc.ucdavis.edu/ed-outreach/ed-programs/trout-in-classroom.html

TERC 2015. Tahoe Environmental Research Center. State of the Lake Report 2015. Released on July 23, 2015.

Thiede 1997. Thiede, G. Impact of lake trout predation on prey population in Lake Tahoe: A bioenergetics assessment. Thesis. Utah State University.

TKPOA 2014a. Tahoe Keys 2014 Aquatic Plant Survey. Prepared by Sierra Ecosystem Associates. December 2014.

TKPOA 2014b. Characterization of Aquatic Plant Fragments in the Tahoe Keys Lagoons. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. December 2014.

TKPOA 2015. Tahoe Keys 2015 Aquatic Plant Survey. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. January 2016.

TKPOA 2016a. Tahoe Keys Skimmer Boat Evaluation. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2016b. Tahoe Keys 2016 Water Quality Sampling Report. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2016c. Tahoe Keys 2016 Sediment Sampling Report. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2016d. Tahoe Keys 2016 BMI Sampling Report. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2016e. Evaluation of Floating Treatment Wetlands for Potential Use in the Tahoe Keys Lagoons. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2016f. Biological Control of Aquatic Plants and Potential Use in the Tahoe Keys Lagoons. Prepared by Sierra Ecosystem Associates. December 2016.

TKPOA 2017. Nonpoint Source Water Quality Management Plan. Prepared for Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates. January 2017.

TKPOA 2018a. Non-chemical Combination Control Methods Test Summary Report. Prepared by Sierra Ecosystem Associates. Draft – January 2018.
TRCD 2014a. Tahoe Keys Aquatic Plant Management Research Project: 2013 Final Report. Prepared by the Tahoe Resource Conservation District, South Lake Tahoe, CA.

TRCD 2014b. Initial Study and Mitigated Negative Declaration for the Lake-wide Aquatic Invasive Plant Control Project. Document prepared for the Tahoe Resource Conservation District boy Hauge Brueck Assoc., LLC. July 2014.

Tribune 2016. Tahoe Keys to apply for herbicide trial in effort to fight aquatic invasive species. Tahoe Daily Tribune. Published September 27, 2016. Website: http://www.tahoedailytribune.com/news/tahoe-keys-to-apply-for-herbicide-trial-in-effort-to-fight-aquatic-invasive-species/

TRPA 2014. Lake Tahoe Region Aquatic Invasive Species Management Plan, California-Nevada. Tahoe Regional Planning Agency. May 2014.

USACE 2012. Smith, C.S., et al. Selective Control of Eurasian Watermilfoil in Houghton Lake, Michigan: 2002-2006. Report prepared for US Army Corps of Engineers. Publication No. ERDC/EL TR-12-15. 2012.

USDA 2000. Murphy, D. D., C.M. Knopp, technical editors. 2000. Lake Tahoe Watershed Assessment: Volume I. Gen. Tech. Rep. PSW-GTR-175. Albany, CA: Pacific Southwest Research Station, Forest Service, US Department of Agriculture; 753 p.

USFS 2013. Basin-wide Native Non-game Fish Assessment, 2011 Annual Report. Revised on February 21, 2013. US Forest Service, Lake Tahoe Basin Management Unit. Lemmers, C., and M. Santora, authors.

USFWS 2013. Endangered Status for the Sierra Nevada Yellow-Legged Frog and the Northern Distinct Population Segment of the Mountain Yellow-legged Frog, and Threatened Status for the Yosemite Toad, Federal Register Vol 78, No. 80. Proposed Rule. April 25, 2013. pp 24472-24514.

USFWS 2014. Lahontan Cutthroat Trout (Oncorhynchus clarkii henshawi). U.S. Fish and Wildlife Service, Nevada Fish and Wildlife

Office, Pacific Southwest Region. Retrieved on January 15, 2015. Last updated April 16, 2014. http://www.fws.gov/nevada/protected_species/fish/species/lct html

USGS 2000. Surface- and Groundwater Characteristics in the Upper Truckee River and Trout Creek Watersheds. WRIR 00-4001. http://pubs.usgs.gov/wri/wri004001/Text/contents.htm

USGS 2009. Rowe, T.G., and K.K. Allander. Surface- and Ground Water Characteristics in the Upper Truckee River and Trout Creek Watersheds, South Lake Tahoe, California and Nevada, July-December, 1996. Water Resources Investigations Report 00-4001. 2009.

Ussery 1997. Ussery, T.A., H.L. Eakin, B.S. Payne, A.C. Miller and J.W. Barko. Effects of Benthic Barriers on Aquatic Habitat Conditions and Macroinvertebrate Communities.

Valley 2015. Valley, R. D. , M.B Johnson, D.L. Dustin, K. D. Jones, M.R. Lauentein, J. Nawrocki. Combining hydroacoustic and point-intercept survey methods to assist aquatic plant species abundance patterns and community dominance. J. Aquat. Plant Manage. 53: 121-129. 2015.

Vander Zanden 2003. Vander Zanden, J., S. Chandra, B.C. Allen, J.E. Reutler, and C.R. Goldman 2003. Historical Food Web Structure and Restoration of Native Aquatic Communities in the Lake Tahoe (California-Nevada) Basin. Ecosystems 6: 274-288.

Van Way 2005. Minute Item Number 66: A Demonstration project to remove an area of a non-native invasive aquatic species, Eurasian watermilfoil from sovereign lands in Emerald Bay, Lake Tahoe, El Dorado County. California State Lands Commission, Sacramento, CA.

Walter 2000. Walter, K. M. Ecosystem effects of the invasion of Eurasian watermilfoil (Myriophyllum spicatum) at Lake Tahoe, CA-NV. University of California Davis.

West Virginia Department of Environmental Protection (WVDEP) 2018. Watershed Management-Biological Monitoring. Accessed January 5, 2018 from https://dep.wv.gov/WWE/watershed/bio_fish/Pages/Bio_Fish.aspx.

Wittmann 2015. Wittmann, M. E., B. E. Kendall, C. L. Jerde, and L. W. J. Anderson. Estimating relative risk of within-lake aquatic plant

invasion using combined measures of recreational boater movement and habitat suitability. PeerJ 3:e845. Retrieved from https://peerj.com/articles/845.

Zeiner 1988. Zeiner, D.C., W.F. Laudenslayer, K.E. Mayer, and M. White, eds. 1988-1990. California's Wildlife. Vol I-III. California Dept. of Fish and Game, Sacramento, California.

7.0 ACRONYMS

AIS: Aquatic Invasive Species
AISCC: Aquatic Invasive Species Coordinating Committee
ACC: Architectural Control Committee
ACRB: Architectural Control Rules Brochure
Al: Aluminum
BMI: Benthic macroinvertebrate
BMP: Best Management Practice
BNR: Biological Nutrient Reduction
CDFW: California Department of Fish and Wildlife
CDPR: California Department of Pesticide Regulation
CEQA: California Environmental Quality Act
CESA: California Endangered Species Act
COC: Chain of Custody
CSLC: California State Lands Commission
CTC: California Tahoe Conservancy
DO: Dissolved Oxygen
EIR Environmental Impact Report
EPA: Environmental Protection Agency
ESA: Federal Endangered Species Act
FIFRA: Federal Insecticide, Fungicide and Rodenticide Act
FTW: Floating Treatment Wetlands
GIS: Geographic information System
GPS: Global Positioning System
HACCP: Hazard Analysis and Critical Control Plan
IMP: Integrated Management Plan
Implementation Plan: Lake Tahoe Aquatic Invasive Species Implementation Plan
IWMP: Draft Integrated Weed Management Plan
LCT: Lahontan Cutthroat Trout
Lahontan Board: Lahontan Regional Water Quality Control Board or Lahontan Board
LTAISCC: Lake Tahoe Aquatic Invasive Species Coordination Committee
NDEP: Nevada Division of Environmental Protection
NDOW: Nevada Division of Wildlife
NDSL: Nevada Division of State Lands
NEPA: National Environmental Policy Act
NH_3: ammonia
NO_2: nitrite
NO_3: nitrate
NPDES: National Pollutant Discharge Elimination System
NPS: NonPoint Source Water Quality Management Plan
O & M: Operation and Maintenance

Regional Plan: Lake Tahoe Aquatic Invasive Species Management Plan
SEA: Sierra Ecosystem Associates
SLT: City of South Lake Tahoe
STPUD: South Tahoe Public Utility District
SWRCB: State Water Resources Control Board
TERC: Tahoe Environmental Research Center
TKB&HA: Tahoe Keys Beach and Harbor Association
TKPOA: Tahoe Keys Property Owners Association
TRCD: Tahoe Resource Conservation District
TRPA: Tahoe Regional Planning Agency
UCD: University of California, Davis
UNR: University of Nevada, Reno
USACE: United States Army Corps of Engineers
USAERDC: US Army Engineer Research and Development Center
USDA: United States Department of Agriculture
USFS: United States Forest Service
USFWS: United States Fish and Wildlife Service
UV: Ultraviolet
VHC: Vessel Hull Clearance
WDRs: Waste Discharge Requirements
WQC: TKPOA Water Quality Committee

8.0 GLOSSARY

Adsorption	Adhesion of atoms, ions, or molecules to a surface.
Assemblage	A collection or gathering of things having the same distinctive features which identify them from the others.
Bathymetry	The measurement of water depth at various places in a body of water or the information derived from such measurements.
Benthic	Relating to the bottom under a body of water.
Biomass	The mass of living matter in a specific area or habitat.
Biovolume	The volume of living cells or plants in a unit volume of water.
Cultural control	A component of integrated pest control management which includes practices that reduce establishment, reproduction, dispersal, and survival of the target species which are not mechanical or chemical in nature. Cultural control can include changing human behaviors that otherwise would promote pest species.
Macrophyte	An aquatic plant that grows in or near water and is either emergent, submergent, or floating.
Mechanical control	Pest control practices which directly harm the target species or make the environment unsuitable for that species.
Nutrient Load	The quantity of nutrients entering an ecosystem in a defined period of time. Of particular concern are the amounts of nitrogen and phosphorus. Nutrient loading is affected by inputs from non-point sources such as surface runoff, erosion, and atmospheric deposition.
Nutrient pumping	Processes by which nutrients are moved from the underlying sediment to the water column above.
Propagule	A vegetative structure that can become detached from a plant and give rise to a new plant.
Residence time	The average time water, or a dissolved substance in water, is contained in a lake or reservoir. The average time a water molecule spends in body of water.
Resource reduction	Management practices that reduce the amount of resources needed, such as reducing water use, minimizing fertilizer use, or otherwise reducing the inputs to a system to decrease the impacts from the management on the natural environment.
Rhodamine WT Dye	A fluorescent dye developed for water tracing applications.
Rhizome	A horizontal underground stem that can produce both shoots and roots.
Systemic	Affecting the entire organism; affecting an entire system.
Turbidity curtain	Also known as silt curtains, these floating barriers are commonly used in marine construction projects to control the silt and sediment in the water body.
Turion	An overwintering bud that can become detached and remain dormant in the water.

Appendix A

Aquatic Herbicides

Appendix A - Aquatic Herbicides

Table of Contents

All references made in this document can be found in the reference section of the IMP.

PREFACE

This appendix to the 2016 IMP describes the regulation and registration of herbicides, the types of herbicides available to control aquatic plant growth, their efficacy, concerns of herbicide use, and lists the potential advantages and disadvantages of aquatic herbicides.

Placement of the herbicide use information in this appendix should not in any way be construed as an indication that the efficacy, utility and proven safety and utility of these products is in question. Inclusion of the use of aquatic herbicides in a fully integrated aquatic weed management plan will likely be essential to meet the Goals of the IMP and to protect Lake Tahoe from the continuing threat from invasive aquatic weeds. However, for the LRWQCB to accept submittal of the IMP under the current WDRs permit, the TKPOA was directed by the LRWQCB to place all text regarding aquatic herbicides in this appendix to the document as stated in its letter dated August 18, 2016 (copy attached).

The TKPOA has been forthright in its approach seeking regulatory approval for a small-scale demonstration of aquatic herbicides combined with non-herbicide methods. The interested public is well aware of these efforts. Input has been solicited and received from numerous agencies, associations, non-profit groups, and the general public in the Tahoe area.

The TKPOA has committed to an extensive research program to investigate a wide range of (herbicide and non-herbicide) methods of aquatic plant control to identify improved methods for future versions of the IMP. This research program includes, but is not limited to, determining which EPA and California EPA approved aquatic herbicides are suitable for the Tahoe Keys lagoons. In addition to approval of their inclusion in the TKPOA IMP by LRWQCB, any application of aquatic herbicides also will require that the TKPOA obtain the necessary regulatory approvals from the State of California (State Water Resources Control Board) and the Tahoe Regional Planning Agency (TRPA). By letter dated January 17, 2017, TKPOA submitted an application for an herbicide demonstration to the LRWQCB and TRPA that would take place in spring 2018.

INTRODUCTION

Chemical control of aquatic plants with registered aquatic herbicides is widely used throughout California and the United States. Aquatic herbicides are used to control Eurasian watermilfoil, curlyleaf pondweed and other nuisance aquatic plants in California (Clear Lake, Big Bear Lake, and the Sacramento-San Joaquin Delta), and in lakes in the states of Washington, Minnesota, and Florida, to name a few of the many locations where herbicides are routinely applied to public waterways. Aquatic herbicides control aquatic vegetation without harming fish or wildlife. Herbicides that have been approved for use in aquatic systems have been extensively studied for efficacy and potential impacts to the aquatic ecosystem such as toxicity to non-target organisms.

REGULATORY AUTHORITIES

The distribution, sale, and use of all herbicides are regulated by the US Environmental Protection Agency (EPA) through the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and by the California Environmental Protection Agency (CalEPA) through the Department of Pesticide Regulation (DPR).

Aquatic herbicides undergo additional scrutiny prior to being registered for use to ensure environmental safety. As part of the approval process, the registrant of an herbicide must test the active ingredient and the formulation of the herbicide for the potential to harm human health and the environment. These tests include human and ecological toxicity studies, as well laboratory and field studies to analyze the fate of the active ingredients in water, plants, fish, and soil as a result of the intended use of the aquatic herbicide.

There are many herbicide products registered for use in the United States and there are approximately 12 active ingredients that are approved for use in aquatic herbicide products in the state of California. Regulation of aquatic herbicides falls under the authority of the Federal Clean Water Act and this regulation is delegated in California to the State Water Resources Control Board and the regional water quality control boards, which approve aquatic herbicides through the National Pollutant Discharge Elimination System (NPDES) permit system and the Aquatic Pesticide Application Plan (APAP) required for aquatic herbicide use. Applicators of aquatic herbicides must be trained and certified by the DPR and must maintain current knowledge of regulations through continuing education.

In addition to obtaining coverage under a state-wide NPDES permit, any application of aquatic pesticide proposed for the Lake Tahoe Basin must be approved by the LRWQCB by obtaining an exemption from the current prohibition on use of aquatic pesticides in the Lahontan Basin.

TYPES OF HERBICIDES

Herbicides for both terrestrial and aquatic use can be categorized in two major groups: contact and systemic. Contact herbicides directly damage the plant tissues at the point of contact and can quickly kill a target plant. Systemic herbicides are first absorbed by the plant, then are distributed, or translocated, throughout the plant where they disrupt normal plant cell functions (Fennimore 2014; Netherland 2009).

Contact Herbicides

These herbicides directly affect the plant tissues and the active ingredient does not travel through the tissues of the plant. Typically, contact herbicides act very rapidly, within minutes to a few hours, depending on concentration and target plant susceptibility but generally do not provide long-term control of aquatic plants. Plant tissues that are not damaged by contact herbicides can regrow. Contact herbicides must remain in the treated area for a sufficient amount of time and at a sufficient concentration in order to kill the

plant tissues. Depending on the aquatic herbicide used, this contact time ranges from a few hours to a few days.

Systemic Herbicides

These herbicides are absorbed by plant tissues and move through the water or food transporting structures to other parts of the plant where they have deleterious effects on normal plant cell functions, such as disrupting photosynthesis, protein synthesis, or growth regulation. This movement of the active ingredient is called translocation. Typically systemic herbicides require longer contact time with the treated plants than contact herbicides, and require more time to completely kill the target plant. The advantage of systemic type herbicides is that they usually provide longer lasting control: translocation of the active ingredient affects the plants' ability to re-grow and can often inhibit the plants' ability to produce flowers and vegetative propagules.

HERBICIDE APPLICATION METHODS

Aquatic herbicides are delivered as concentrated liquids or as solid granules or pellets. The herbicide product can be applied to the water or to the sediment surface where it can be absorbed by the roots and rhizomes. The volume of water in the treatment area must be known in order to correctly determine the amount of herbicide product to apply to control a particular nuisance aquatic plant.

In some situations, combinations of herbicides may give better control of aquatic plants by providing a broader range of modes of actions and active ingredients. For optimal efficacy of aquatic herbicides, the characteristics of the product, physical and biological conditions of the treatment site and susceptibility of the target plant must be understood. This concept is summarized in Figure A-1.

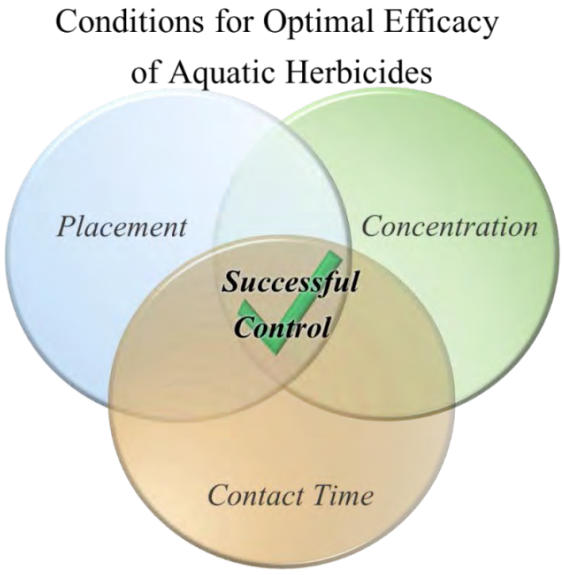


Figure A-1. Herbicide Efficacy
(Source: K. Getsinger, L. Anderson)

ENVIRONMENTAL FATE

There are many physical and biological variables that can affect the environmental fate of herbicides. Physical processes such as diffusion and dispersion can be influenced by wind or water currents as the compound moves from the application area where it is in high concentration to areas of low concentration. The formulation of the aquatic herbicide can affect the release rate of the active ingredient so that the application can be tailored to match site-specific conditions and to minimize movement away from the treated area.

Herbicide action can be affected by chemical processes of volatilization, hydrolysis, and adsorption to soil or sediment particles. Herbicide molecules are subject to degradation by ultraviolet light and microbial action. These processes effect how well the herbicide works on the target plant.

MONITORING HERBICIDAL CONTROL METHODS

Monitoring methods used to assess efficacy, non-target effects and environmental fate of aquatic herbicides must be tailored to the application method, the specific product used, and the use of the site and the water at which the product is applied.

Herbicide concentrations can be monitored quickly and accurately at the application site and in the surrounding body of water. Affordable testing systems such as enzyme-linked immunoassays (ELISA) are available for several of the aquatic herbicides approved for use in California and analysis can be completed in a timely manner to ensure that concentrations for efficacy have been met and to meet regulatory requirements.

In addition to monitoring for efficacious levels of herbicides, additional monitoring is necessary to ensure that potential sensitive uses of water, such as potable, domestic and commercial uses, irrigation, and livestock watering, are protected. Water sampling stations must be properly positioned to capture information on the dispersion on the active ingredient and to detect residues outside of the treatment area. Depending on the type of product and application methods, herbicide residues may be dispersed vertically across the water column or be localized near the sediment layer. The location and depth of water sampling as well as frequency and analytical testing parameters must be determined based on type of herbicide applied. Monitoring typically includes the following:

(1) Dissolved oxygen (surface and bottom)
(2) pH (surface and bottom)
(3) Temperature (surface and bottom)
(4) Turbidity (surface and bottom)
(5) Nutrients (nitrates and phosphorous, surface and bottom)

In addition to the tests listed above, testing for photosynthetically active radiation (PAR) at the water surface, mid-depth and at the bottom would measure for impacts to the plant canopy and habitat as a result of aquatic plant management.

Water samples must be handled properly to maintain their integrity and to assure quality control. Crews must be properly trained and supervised in all sampling techniques and chain of custody requirements. It is unlikely that herbicide residues will contact groundwater sources in the area due in part to their adsorption to soil particles which limits movement away from the application site. As a precaution, pre- and post-application water samples will be taken at one or more potable water pump stations within the Tahoe Keys. The duration of sampling will be determined in consultation with the South Tahoe Public Utility District, local water purveyors, and the Lahontan Water Board.

CONCERNS OF HERBICIDE USE

Non-target Impacts

There is a low risk of acute impacts to the aquatic ecosystem when aquatic herbicides are applied by trained applicators following the herbicide label criteria. The aquatic herbicides registered for use in the US and in California are relatively non-toxic to fish and humans because their modes of action affect plant processes, such as photosynthesis, which are not found in animal organisms. None of the registered aquatic herbicides are classified as carcinogens. Many can be used in irrigation systems, near potable water intakes and many have no post-application restrictions on consumption of the treated water by animals, swimming, or fishing.

As discussed above, physical variables can cause an herbicide to move from the site of application. Prior to application, weather conditions such as wind and temperature, must be monitored to ensure that the herbicide does not physically move outside of the treatment area and affect non-target organisms. The NPDES permit that is required for any application in Waters of the US includes descriptions of both application requirements, restrictions, and monitoring protocols.

Herbicide Resistance

Another important consideration in using any herbicide is the risk of inducing resistance in the target plant population. Herbicide resistance has been well-documented in terrestrial plants and has also been demonstrated in aquatic plant species. It is a result of continued exposure to the same active ingredient and the same mode of action which does not completely eradicate the target plant population. The surviving plant population then becomes a source of plants that resist the active ingredient. The potential to develop herbicide resistance can be reduced by using different herbicides

SUMMARY OF CHEMICAL CONTROL OF AQUATIC PLANTS

Aquatic herbicides can be effective in controlling the growth of unwanted vegetation. Aquatic herbicides are used in many aquatic plant management plans and can be integrated with a variety of control methods. When properly used by trained applicators, herbicides effectively control aquatic plants without harming fish or benthic organisms, wildlife, or humans. Proper use of approved aquatic herbicides can result in sustained

control of aquatic plants lasting over several growing seasons, reducing the need for employing additional control methods.

Aquatic herbicides must go through a rigorous testing process before they can be registered with the US EPA and the California EPA for use in aquatic systems. These approved herbicides pose no significant threat to the environment or public health when used in accordance with labelling instructions. As part of the registration and approval process, the US EPA also identifies application restrictions for the herbicide.

Advantages

- Approved aquatic herbicides allow managers to target specific plant species and avoid impacts to non-target species.
- Herbicides offer rapid, and, in many cases, long-lasting control.
- Herbicides can easily control aquatic weeds in areas such as around docks and other physical structures that usually limit the use of mechanical methods such as harvesting and rotovating.
- Use of herbicides in spring can significantly reduce the seasonal biomass and impacts of aquatic weeds, thus reducing the need for extensive and continual management through other means such as harvesting.
- Herbicide treatments are cost-effective methods to control plants.
- Monitoring methods for residual herbicide in water surrounding the treatment area ensure safety.

Disadvantages

- Herbicides must be handled carefully. Applications must be made by trained crews that are under the supervision of state-certified applicators to ensure that herbicides are handled safely and applied in the proper dose.
- Herbicides with limited target-specificity are not as effective if more than one target plant species is present. In these instances, combinations of herbicides may be needed for control which could incrementally increase costs of control.
- A rotation of herbicides with different active ingredients is needed to avoid developing herbicide resistance in the target plant population.
- Herbicides must be applied at the proper time during the growing season for best control. This requires monitoring of the stage of growth of the target plants.
- Some herbicides have non-target effects on benthic organisms.
- Some herbicides can persist in the water.
- Rapid death of vegetation can temporarily lower the dissolved oxygen in the water of the treated area. This only occurs when
    - a large biomass of plants has been allowed to accumulate;
    - water movement is severely restricted;
    - water temperatures are high and have reduced capacity to retain dissolved oxygen.
- Loss of vegetation after treatment can temporarily reduce habitat for fish and benthic organisms.

SUITABILITY TO THE TAHOE KEYS LAGOONS

There are several registered aquatic herbicides that have been shown to control the nuisance aquatic species of the Tahoe Keys lagoons and which can be safely used in combination with other control methods such as bottom barriers, mechanical harvesters, or diver-assisted suction. The contact aquatic herbicide endothall has been used to control curlyleaf pondweed, coontail, and Eurasian watermilfoil. The systemic aquatic herbicides imazamox and penoxsulam have been registered for use on Eurasian watermilfoil and curlyleaf pondweed.

As described in Section 4.3 of the IMP, five Success Criteria have been selected to measure the progress made in gaining control of the three target invasive aquatic plants in the Tahoe Keys lagoons: Eurasian watermilfoil, curlyleaf pondweed, and coontail. The Expected Success Criteria for two control methods, improved mechanical harvesting and improved fragment capture and bottom barrier installation, are compared to the expected success criteria when herbicide use is integrated as presented in Table A-1 below:

	Control Method	Improved Mechanical Harvesting and Fragment Capture	Bottom Barrier Installation	With Herbicide Use Integrated
1	Biovolume of target plants reduced 90% by 2020	20%	5%	100%
2	VHC sustained June to October	10%	60%	80%
3	Measureable increase in native plants as percentage of all aquatic plants	10%	50%	75%
4	Reduction in fragment production	5%	70%	90%
5	Low levels of adverse non-target effects	70%	70%	90%

Table A- 1: Comparison of Control Measure Effectiveness

The use of aquatic herbicides combined with other suitable aquatic control methods could achieve high levels of success in controlling the invasive aquatic plants found in the Tahoe Keys lagoons.

2016 AQUATIC HERBICIDE RESEARCH PROJECTS

The following projects were conducted in 2016 to investigate potential movement of aquatic herbicides in the Tahoe Keys lagoons and to study the efficacy of aquatic herbicides in a mesocosm study of plants that mimicked conditions found in the Tahoe Keys lagoons.

Rhodamine Water Tracer Dye Study

The IMP is based on the established principles of Integrated Pest Management, defined as a coordinated system of technological and management practices to safely control pests in a long-term, environmentally sound, and economical manner. Two key principles

of IPM include optimal application and effective methods to achieve control while protecting the environment along with sufficient monitoring of pest populations so that actions can be adjusted to sustain control as conditions change. The inclusion of federally and state approved aquatic herbicides to the IMP meets the accepted definitions and strategies for effective implementation. However, the use of approved herbicides has become controversial in the area of the Tahoe Keys lagoons and additional study to demonstrate the environmental fate of these products was requested by the public to assure the safety of their use.

To study the potential movement and dissipation of aquatic herbicides in and around the Tahoe Keys lagoons, the water soluble, fluorescent dye Rhodamine WT (RWT) was applied in the lagoons in 2016 as a surrogate for aquatic herbicides. This tracer dye is approved by the US EPA for use in potable water for plumbing tracing and leak detections, among other applications.

A previous study in 2011 showed that in late spring RWT dye remained within local sites for 3 to 5 weeks. The 2016 study specifically addressed the question of how dissolved materials (represented by dye) move near the channel openings on the Main and Marina lagoons. The 2016 study confirmed that early June applications resulted in no movement to Lake Tahoe, even from a site near the west channel of the Main Lagoon. Later applications (late June) resulted in transient movement into the channel. The 2016 studies also showed that use of double containment curtain barriers can restrict the movement of dissolved materials for contained sites by 98% (Anderson 2016).

Mesocosm Study

The use of small scale, outdoor mesocosms for herbicide evaluations are a standard, post-laboratory method to assess the efficacy and species selectivity of approved federal and California-EPA aquatic herbicides. The 2016 Mesocosm Study utilized replicated tank mesocosms with secondary containment in which target aquatic weeds from the Tahoe Keys lagoons were grown and subsequently exposed to aquatic herbicide products. The mesocosms were exposed to natural light and subjected to natural changes in day length for plant growth and during the herbicide exposures. The mesocosm system was plumbed so that there was no contact or movement of the herbicides into any surrounding waterbody and used plants and sediments from the Tahoe Keys lagoons. The water supply for the study was taken from Lake Tallac Lagoon. At the end of the experiment, levels of active ingredients of the herbicides were measured until no detectable active ingredients were detected. Water was then released into settling basins adjacent to the TKPOA circulating/treatment plant. Plant material and sediments exposed to aquatic herbicides during the course of the study were disposed out of the Tahoe Basin by the local solid waste handling company.

The mesocosm system and protocol for the 2016 project was the same as that used in 2001 and 2002 by Anderson, Goldman and Duvall to assess the efficacy of triclopyr, endothall and fluridone herbicides for control of Eurasian watermilfoil. This study extended this assessment by including curlyleaf pondweed and potential new aquatic

herbicides (i.e., Procellacor). The results of these types of Mesocosm studies, together with TKPOA's proposed 2018 combination herbicide/non-herbicide demonstrations, will help determine the potential suitability of future aquatic herbicide use in the IMP tool kit.

Appendix B

Letter from Lahontan Board

CALIFORNIA Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

Lahontan Regional Water Quality Control Board

August 18, 2016

Kirk J. Wooldridge
General Manager
Tahoe Keys Property Owners Association
356 Ala Wai Boulevard
South Lake Tahoe, CA 96150

Conditional Acceptance of Tahoe Keys Property Owners Association (TKPOA)'s Integrated Management Plan and Nonpoint Source Plan

I am accepting TKPOA's May 31, 2016, Integrated Management Plan (IMP) and Nonpoint Source (NPS) Plan, provided TKPOA meet three important conditions. TKPOA representatives orally agreed during a July 8, 2016, meeting with Water Board staff to meet the following conditions:

1. By October 1, 2016, submit a revised IMP where all text regarding use of aquatic herbicides has been removed from the body of the IMP. It is acceptable to place text about aquatic herbicides into an appendix to the IMP.
2. Since TKPOA has chosen to document coordination with the City of South Lake Tahoe (CSLT) regarding shared storm water facilities, submit a statement documenting TKPOA's plans for meeting and coordinating with the CSLT about storm water issues. The statement must address how the shared facilities are being inspected and maintained, and how TKPOA is handling the non-shared storm water runoff to ensure there are no increases in pollutant loads.
3. By January 31, 2017, as part of the annual update to the IMP submittal, include an assessment and evaluation of the internal cycling and loading of nutrients, primarily nitrogen and phosphorus. The assessment should include the water and sediment quality data collected to date, and can cite literature values to estimate nutrient uptake by aquatic plants.

I am encouraged that TKPOA has been responsive to comments by the public and to Water Board comments on the August 11, 2015, public draft of the IMP. The input received from stakeholders, regulators, and the public in the process of developing this revised IMP has enabled TKPOA to revise its IMP appropriately to produce a better document that can be used a template for other entities who are experiencing similar aquatic invasive plant problems.

We look forward to continued work with you towards improvements in water quality and enhancement of beneficial uses of water in the Tahoe Keys lagoons. . Please contact me at patty.kouyoumdjian@waterboards.ca.gov (530) 542-5412 or Bruce Warden

bruce.warden@waterboards.ca.gov (530) 542-5416, if you have any questions. Thank you for your cooperation.

PATTY Z. KOUYOUMDJIAN
EXECUTIVE OFFICER
LAHONTAN WATER BOARD

Cc: Tahoe Regional Planning Agency, Dennis Zabaglo
Tahoe Water Suppliers Association, Madonna Dunbar
League to Save Lake Tahoe, Darcie Goodman-Collins
Tahoe Area Sierra Club, Harold Singer
California Department of Fish and Wildlife, Joel Trumbo
California Tahoe Conservancy, Penny Stewart
Tahoe Resource Conservation District, Nicole Cartwright
South Tahoe Public Utility District, John Thiel
City of South Lake Tahoe, Jason Burke
US EPA Region 9, Jacques Landy
UC Davis Tahoe Environmental Research Center – Geoff Schladow
University of Nevada at Reno- Sudeep Chandra
Sierra Ecosystems Associates, Rick Lind

BW/dk/T: TKPOA IMP NPS cond acceptance