Aquatic Plant Boom Assessment in Spring Lake

Meadows Center for Water and Environment

Texas State University

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Purpose of Spring Lake Vegetation Boom Assessment

Spring Lake offers a pristine habitat for both aquatic flora and fauna. The clear, spring fed waters and stable temperatures allow for abundant growth of the numerous species of submerged aquatic macrophytes found in the lake. Native species that are commonly found in the lake include *Cabomba caroliniana* (fanwort), *Myriophyllum heterophyllum* (water-milfoil), *Ludwigia repens*, *Sagittaria platyphylla* (arrowhead), *Ceratophyllum demersum* (hornwort/coontail), and endangered *Zizania texana* (Texas wild-rice). Non-native species that are commonly found include *Myriophyllum spicatum* (Eurasian-milfoil) and *Hygrophila polysperma.*

Due to the large areas of submerged aquatic vegetation and high rate of growth, regular lake operations must include an aquatic harvester to help keep the growth from reaching the surface. This is to allow for continued operation of glass-bottom- boats tours, educational classes, and dive training programs within the lake. The aquatic harvester is used to keep the top meter of water clear of vegetation in designated areas and removes approximately 15 to 20 boatloads per month. Consequently, the combination of harvester activities, standard lake operations, and the growth rate of the aquatic vegetation result in large amounts of the vegetation becoming dislodged or broken off, which float downstream and into the San Marcos River.

Once in the river, there are more species of aquatic macrophytes present, but most notable is the increased quantities of Texas Wild-Rice (TWR). TWR forms robust emergent stands in dense areas throughout the upper sections of the river. These stands collect the floating vegetation that comes out of the lake and forms dense floating vegetation mats that cover sections of the TWR and surrounding vegetation. The areas where vegetation mats are an issue are from the outflow of Spring Lake downstream through the City Park Reach. The primary species that is found within the vet mats is *Ceratophyllum*, which is not commonly found in the San Marcos River, but is highly prevalent throughout the lake. The accumulated vegetation mats reduce available light and limit photosynthesis while also interfering with normal flow patterns. If left unchecked, these vegetation mats will kill off the cover vegetation, including the endangered TWR.

The Edwards Habitat Conservation Plan (EAHCP) includes a minimization and mitigation measure to reduce the negative effects of vegetation mats on areas of native aquatic vegetation, primarily TWR, within the San Marcos River (EAHCP Section 5.4.3.2) Currently there are two separate contracts that target vegetation mat removal from stands of TWR. These combined efforts are not sufficient for the control of downstream vegetation mats given the constant supply and volume of vegetation mats originating in Spring Lake.

In an attempt to help reduce downstream vegetation mat buildup, the idea was proposed to test some additional aquatic vegetation collection methods within Spring Lake. Large floating vegetation booms are commonly used in aquatic environments to collect both floating vegetation and floating debris. The idea was that 2-3 of these booms could be placed downstream of standard lake operations so that they could collect the dislodged vegetation before it is discharged into the river. The harvester could then remove all the collected vegetation from the booms on a regular basis as part of normal operations. The intent was for the additional effort to capture the vegetation within the lake to significantly reduce the amount of effort and cost required to remove the vegetation mats within the river. This would also be a more effective way to mitigate the negative effects of vegetation mat accumulation on TWR and the impact that the removal process has on native vegetation.

Initial Location Testing

The first step in identifying possible placement points for the temporary booms was to use aerial imagery of Spring Lake to identify any areas of potential interest. These areas would require access to the bank, a depth that the harvester could operate in, and be located in the main flow path that a majority of the vegetation travels prior to exiting the lake. Three potential sites were considered that met these criteria along with recommendations from Spring Lake Operations Staff (see Figure 1).

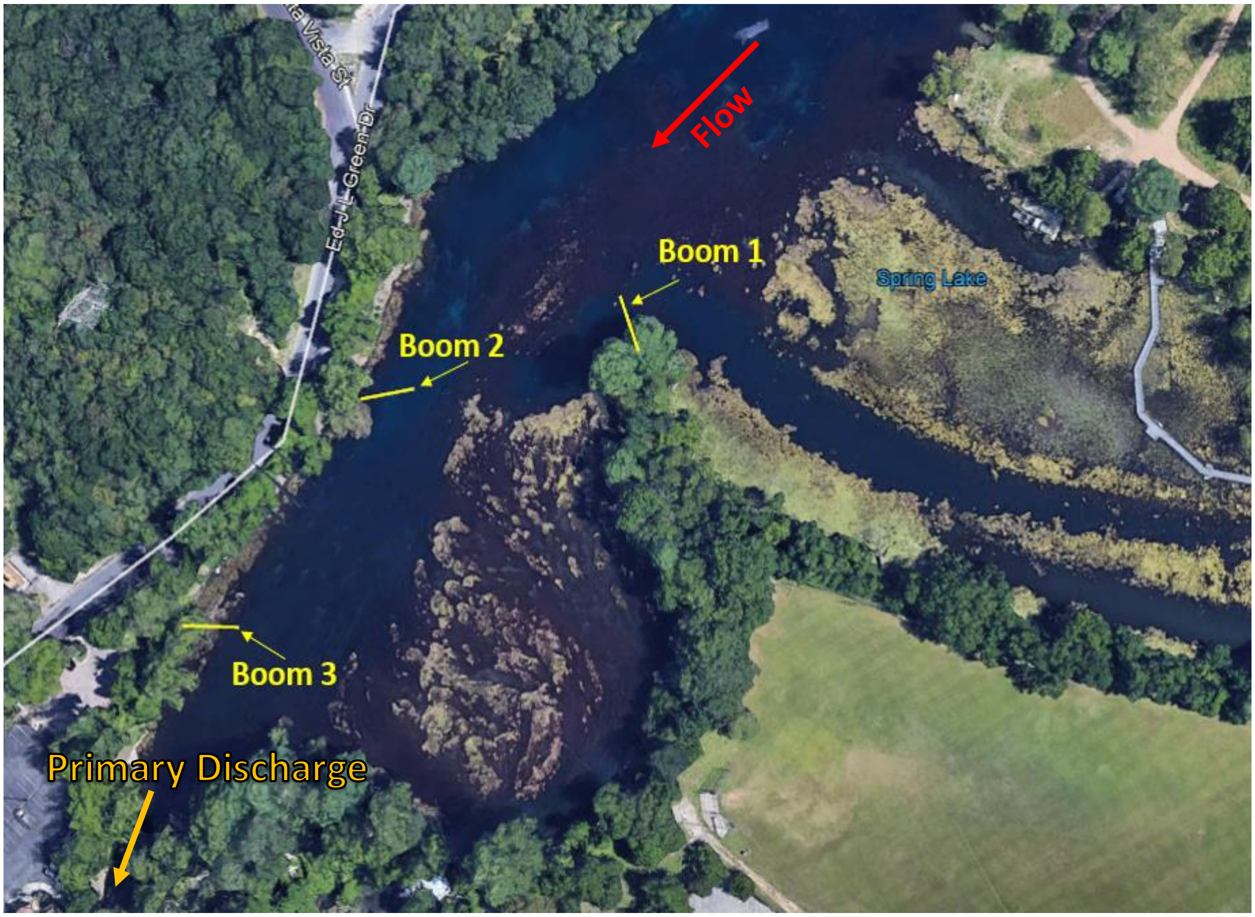


Figure 1. Potential placement sites before any testing.

Each site was inspected by scuba divers to ensure the area was free of obstructions and that the booms could be properly anchored to the bank. The contour of the lakebed was also taken into consideration. The temporary booms that were to be used for initial testing were 50 feet in length, so 50-foot ropes were setup at each location to mimic the booms. A flow test was conducted using tennis balls to simulate floating vegetation. The balls were placed in various locations throughout the lake by kayakers representing areas of known or possible sources of vegetation. The paths of the balls were then observed via drone and kayakers. The test concluded that only the boom 2 and 3 locations were in the flow path of vegetation (tennis balls) (see Figure 2). Boom 2 location showed to be the most likely to capture the most vegetation as the downstream flow patterns started to split between the two spillways before the location of Boom 3. Based on these empirical tests, boom locations 2 and 3 were selected for further assessments.

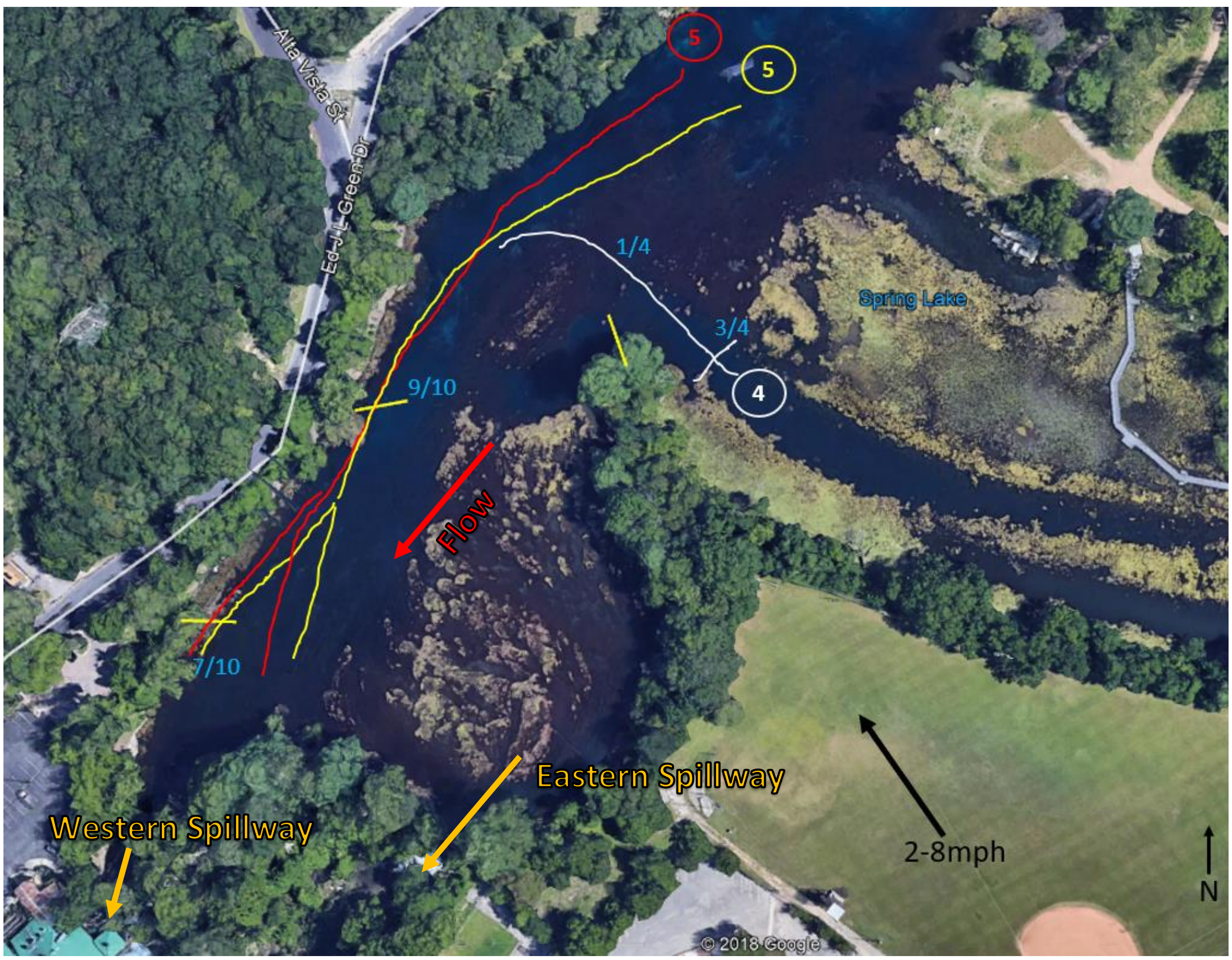


Figure 2. Flow pattern testing, using tennis balls, supported both locations 2 and 3, but not location 1. The numbers show how many tennis balls were released at each location (red, yellow, and white circles) and how many made it through each subsequent checkpoint.

Installation of Temporary Booms

The Meadows Center for Water and the Environment (MCWE) Habitat Conservation Crew (HCP crew) deployed a, 50 foot by 4-foot deep, floating sediment curtain (boom) at location 3 where water depths ranged between 1 to 5 feet over the 50 foot span. This allowed for a 1 foot of gap below the boom for water flow and aquatic fauna transit. Both boom skirts were made from a solid, non-permeable, material that impeded the flow of water. The boom placement incorporated a near shore gap to facilitate water movement and keep the captured vegetation from being diverted around the boom. T-posts were installed in this gap to capture vegetation while minimizing the impedance of flow through the gap.

The initial boom was placed at location 3 using multiple T-posts installed vertically, in a line coming out from the bank, at 1-2 foot spacing, creating a gap of about 5 feet. Four 5-gallon buckets of concrete, weighing 80lbs each, were placed on the stream bed near the outer end of the boom attachment point. Steel cable (1/4 inch) was used to connect both the top and bottom corners of both ends of the boom to the anchor points. A red buoy was used to mark the area where the steel cable ran as a safety measure for the harvester and glass bottom boat operators. The buckets were moved to adjust the boom so that the harvester could easily enter the upstream side of the boom to collect any accumulating vegetation and provide room for glass-bottom-boat operations (see Figure 3).

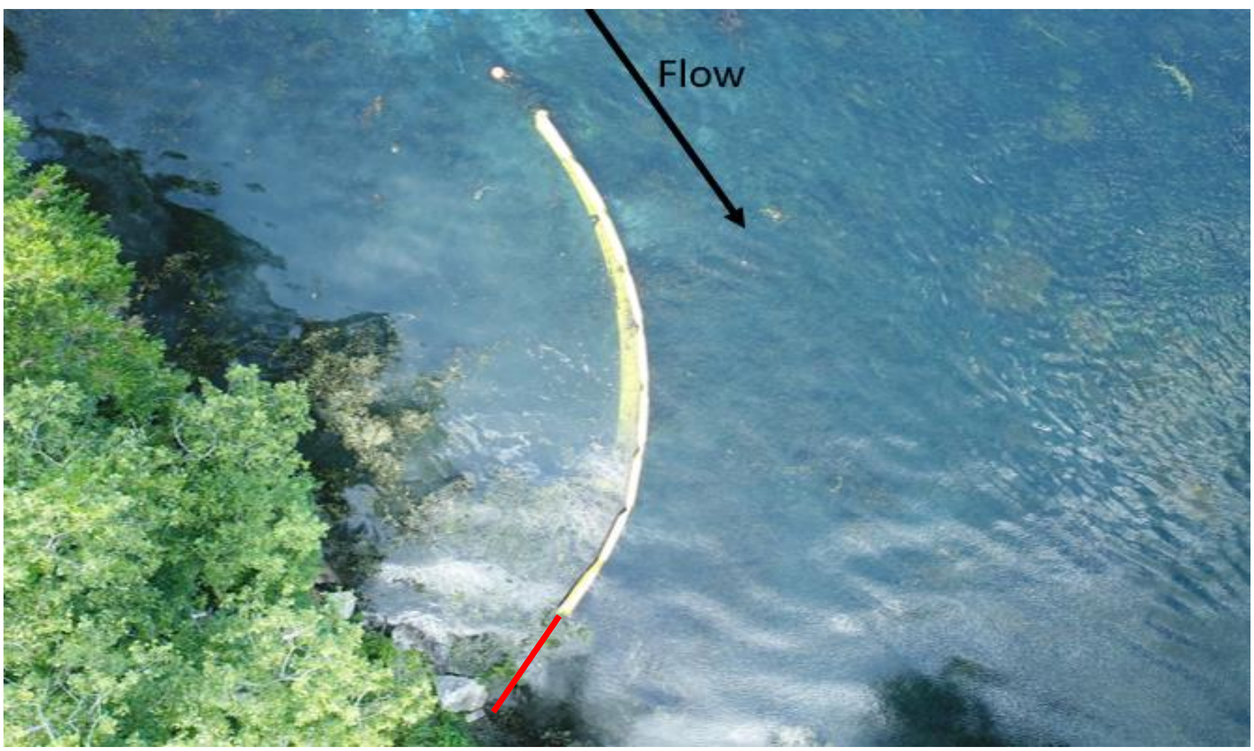


Figure 3. Aerial view of boom 3 location with the temporary boom installed. Red line indicates t-posts location.

Initial field testing determined that the outer anchor point was insufficient, as both flow and harvester activity caused the boom to shift. An additional four weighted buckets were added to the outside end of the boom anchor point, with the top and bottom separately connected to four weights each. The boom's angle was adjusted multiple times to allow for better access by the harvester and to correct for any shifting caused by harvester activities. This final configuration and location was tested over a four-week period.

At the end of the four-week period, boom 2 was installed. This allowed for an observation period to make adjustments to the installation process or setup. For the second boom, the same deployment process was utilized. Water depths at the boom 2 location included depths up to 16 feet at the outer edge of the boom and therefore a 50 foot by 5-foot deep boom was used at this location. The deployment included a similar gap of about 5 feet along the bank containing T-posts and the outer end was anchored to eight 80lb weight buckets using steel cable.

Performance of Temporary Booms

Two weeks prior to boom deployment, a downstream monitoring site was selected and monitored to quantify the amount of vegetation mat accumulation. Vegetation mat removal occurred once a week on Fridays, weather and flow permitting. The monitoring area was located below Spring Lake Dam downstream to the 1st walking bridge in Sewell Park (see Figure 4). The HCP crew removed the vegetation mats by hand, using small duck boats to collect the vegetation, and transferred it to a trailer or the back of a pickup. Both the pickup bed and trailer capacities were calculated and the percent volume for each removal session was recorded and reported as cubic meters of vegetation removed.

Figure 4. Areas in pink show the normal location for vegetation mat accumulation that were removed to quantify buildup on a weekly basis. Yellow lines mark the boundaries of the collection area. Spring Lake Dam Reach on left. Sewell Park Reach on the right.

After boom installation, accumulated vegetation on the booms was removed as part of normal lake operations, which was typically 2-3 times per week (see Appendix A1). The amount of vegetation collected by harvester operations at the booms was quantified by level of removed vegetation within the harvester collection bin and reported as cubic meters of vegetation removed.

Both temporary booms started capturing vegetation almost immediately upon installation. Once both booms were in place, it was clear that boom 3 was collecting more vegetation and at a faster rate compared to boom 2. Both aerial imagery and dive inspections supported this, as seen in Figure 5. Since boom 3 had a more appropriate skirt length for the depth, it was able to collect more vegetation and could keep more of the vegetation in place during harvester removal. Boom 2 had a gap of almost ten feet between the skirt and the lakebed which allowed for vegetation to easily flow underneath the skirt, especially as the shallow area filled with vegetation and diverted the flow path toward the deeper section of the boom (see Appendix A2).

Figure 5. Aerial imagery shows boom 2 at full capacity before vegetation started to flow underneath the skirt (Left). Imagery of boom 3 shows that it was able to hold more at full capacity, with vegetation extending out past the opening (Right).

Combined harvester removal from both temporary booms had an average of 1.32 cubic meters of vegetation per collection, over 21 events. During the same period, vegetation collection in the river resulted in an average of 8.87 cubic meters per removal event, over nine events. Appendix A3 shows the collection data for harvester activity, boom collections, and river vegetation mat removal standardized into cumulative weekly quantities.

Both booms experienced the buildup of vegetation on the outside boom end (lake side) and on the anchor cables (see Appendix A4). This caused the booms to shift multiple times before the additional weight was added. The accumulated vegetation at boom 3 was sufficient to cause a tear in the lower corner of the skirt material that required reinforcement. A floatation buoy was connected directly to the anchors to prevent this from occurring again.

A separate test was conducted in the upper most section of the river, immediately downstream of Spring Lake Dam at the upper section of the test reach, in an attempt to quantify vegetation mat dynamics concurrent while the harvester was removing the collected vegetation from the temporary booms. A series of T-posts were setup perpendicular to the flow, about 60 feet below the western spillway (main flow path from the lake), in two to three-foot intervals (see Appendix A5) The intent was to capture vegetation before it dispersed downstream into the lower river reaches. The T-posts were effective in capturing a large portion of downstream drifting hornwort and milfoil, and is associated with the observation that these species do not fragment into smaller pieces when going over the spillway. The initial setup utilized six T-posts with PVC covers, but observations indicated that they did not extend out into the river far enough and needed to be placed closer together to capture more vegetation. The second setup used T-posts set at less than two-foot intervals and extended out further into the river. A second row of T-posts was offset downstream to add additional collection points. Although the T-posts were deployed for two hours, it was observed that entrapment of vegetation was at maximum capacity after only an hour with subsequent vegetation transiting downstream around the accumulated mats on the posts. All the captured vegetation was removed from the T-posts and quantified by volume. Approximately four cubic meters were collected during the test period and quantified the extent of downstream vegetation dislodged from the booms within Spring Lake during harvester boom operations. These data suggest that upwards of 30 cubic meters/week of aquatic vegetation exits Spring Lake into the river during summer months.

Modifications and Installation of Custom Booms

Based on initial testing and boom performance using the original sediment curtains, two custom Abasco turbidity curtains were ordered to extend the length of the booms farther into the flow path within the lake and included a deeper skirt for the boom 2 location that tapered from four feet near the shore to eight feet at the deeper end to follow the lake bed contour at that location. Both skirts were constructed of permeable material to facilitate less resistance to water flow and incorporated reinforced connection points on each end to reduce damage observed during the initial testing with heavy volumes of vegetation buildup.

Boom installation setup was modified with the installation of T-posts near the bank at the opposite angle used previously (see Appendix A6). This modification was to allow access for the harvester further into the area where the majority of the vegetation collected. The T-posts were installed more closely together in an attempt to maximize collection in the open gap and 2 additional T-posts were installed to push the boom further out into the main flow path within the lake. Existing Spring Lake glass bottom boat operations precluded extension of the booms farther into the flow path of the lake (see Figure 6).

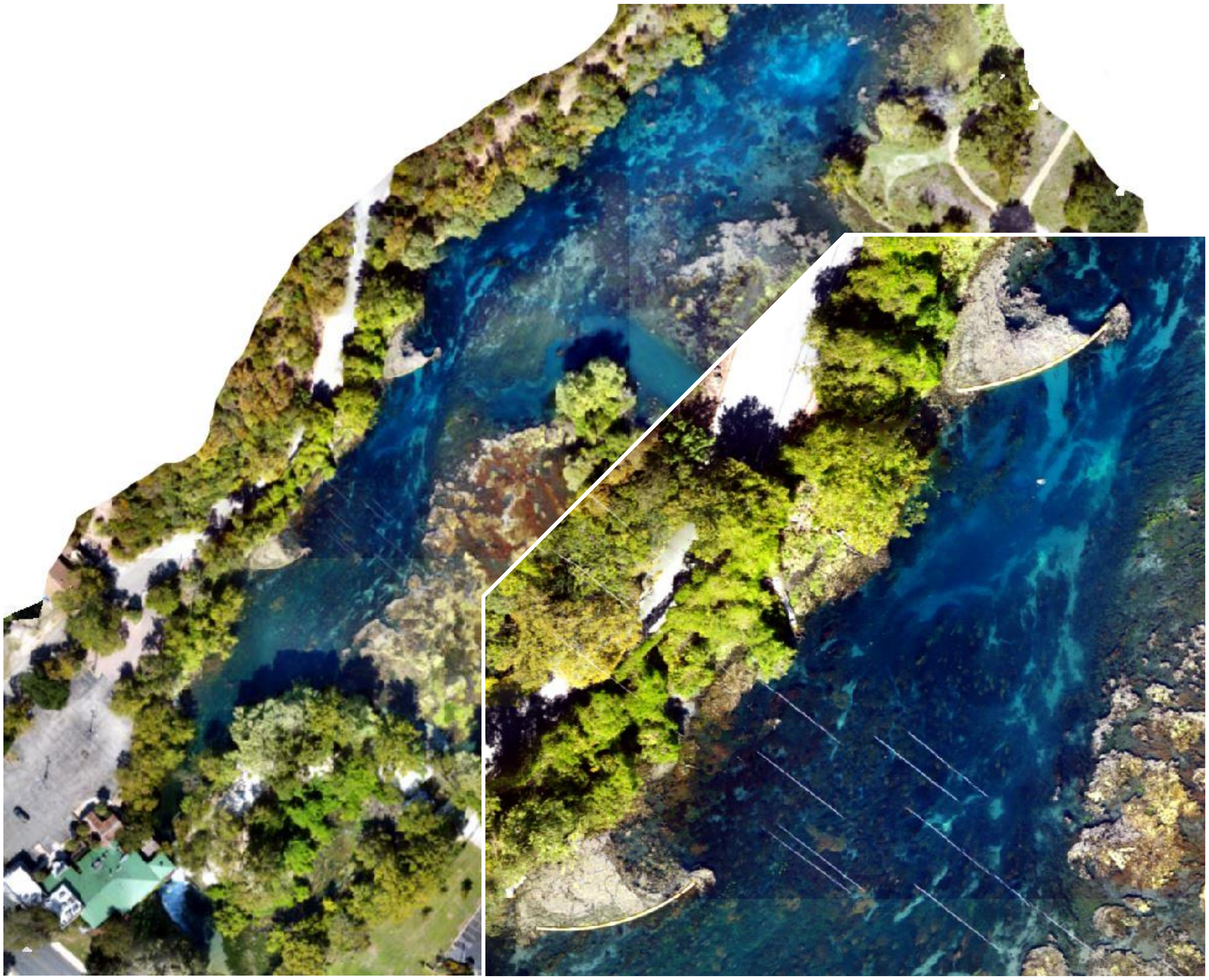


Figure 6. Aerial image of custom booms with the modified setup, extending further out into the main channel and with angled t-posts near bank. Inset is a zoomed in view.

Performance of Custom Booms

After the installation of the custom booms, nine harvester collection events occurred with an average of 1.75 cubic meters per removal. This was higher than the average of 1.32 cubic meters per removal with the previous booms. During the same period, downstream removal resulted in an average of 6.49 cubic meters per removal event, over five events. This was less than the 8.87 cubic meters per event during the period when the previous booms were installed.

The new layout and size of the booms provided easier harvester access when removing vegetation from the booms. This configuration and improved vegetation removal by the harvester resulted in less observed floating vegetation downstream of Spring Lake during harvester boom removal activities as compared to the initial booms. None of the damage that occurred to the temporary booms occurred to the custom booms.

The previous problem of excessive vegetation building up along the entire depth of the boom curtain on the outside (lake) end of the booms still occurred with the custom booms. However, even though a large amount of vegetation built up on the lake end of boom 2, it did not appear to hinder the performance of the boom nor did it cause the boom to shift due to the increased weight of the anchor point.

It was observed that boom 3 appeared to fill up faster compared to boom 2 with both the temporary and custom booms. Part of this was attributed to the dislodged vegetation from boom 2 floating down stream and getting captured in boom 3. There is also large amounts of aquatic vegetation stands present between the two booms that contribute vegetation fragments solely to boom 3. Also, depending on wind direction and intensity, additional vegetation comes from the slough arm of Spring Lake and only collects at boom 3.

Conclusion of Boom Effectiveness

The booms successfully collected dislodged aquatic vegetation within Spring Lake before it transited to the river. The custom booms, incorporating higher permeability and lake contour matching were more effective than the temporary booms and had less operational complications overall. The aquatic vegetation collection data, shown in Table 1, suggest that the custom booms were approximately 33% more effective than the temporary booms when comparing the averages. The average downstream vegetation mat accumulations decreased by about 10% once the custom booms were installed. Comparing the pre-boom to the custom boom test period vegetation mat collections, there was about a 11% increase in the average volume per collection event. There was both a seasonal increase and decrease in vegetation mat removal volumes that effected this comparison. During the 23 weeks covering the boom deployments, the average weekly volume of vegetation mat removal from the booms was 2.28 cubic meters while the downstream monitoring area averaged 6.14 cubic meters/week. During the test period, the largest volumes collected within the monitoring area of the river were between early July to late August. The harvester-based boom collections were more variable over time, but were also larger between mid-June thru late August compared to other months. The complete collection data for the assessment period is provided in Appendix A3.

	Single Temporary Boom Removal Events	Dual Temporary Booms Removal Events	Custom Booms Removal Events	River Vegetation Collection – Pre-Boom	River Vegetation Mat Collection - Temporary Booms	River Vegetation Mat Collection - Custom Booms
Average (m^3)	.88	1.32	1.75	5.87	7.25	6.49
Events	10	21	9	5	15	5
Total (m^3)	8.84	27.73	15.79	29.34	108.78	32.45

Table 1. Collection averages and number of events for River Vegetation Mats before and during boom test and boom removal events for each phase of boom test.

There is no clear correlation between the amount of vegetation collected from the booms and the amount of vegetation mat removed from the river (see Figure 7), nor did the flow rate (CFS) have any effect on vegetation mat removal volumes. When comparing the amount of vegetation captured in the booms to the amount of vegetation mat removed in the river, there is little to know relationship with $R^2 = 0.08$ (see Appendix A7). If the booms were effective, then it is expected that this would be a negative relationship showing that as boom capture volumes increase, the vegetation mat removal volumes would decrease. When comparing the amount of vegetation removed by the harvester per week to the combined total of vegetation captured by the booms and vegetation mat removed in the river, accounting for the total amount of vegetation that would have been discharged into the river, there was a positive correlation with a $R^2 = 0.59$ (Appendix A8). Harvester removal per week compared to just the vegetation mat removal amount per week also had a positive correlation ($R^2 = 0.55$). This suggest that an increase in harvester removal activity in Spring Lake results in increased accumulation of vegetation mat in the river, but that the boom collection amount contributed little to the overall amount collected. It must be noted that the vegetation mat removal area did not account for all vegetation being discharged into the river but represented an area with significant buildup that could be consistently removed from. Both suggest that an increase in harvester removal activity in Spring Lake results in increased accumulation of vegetation mat in the river, but that the boom collection amount contributed little to the overall amount collected. These comparisons suggest that even though the booms were successful at capturing vegetation, the quantity captured was insufficient compared to the overall quantity being discharged from the lake. The number of boom collections events does not show a correlation with the overall quantity removed per week either (see Appendix A9), noting that for week 35, both temporary booms were removed and there was a larger quantity of accumulated vegetation in the river.

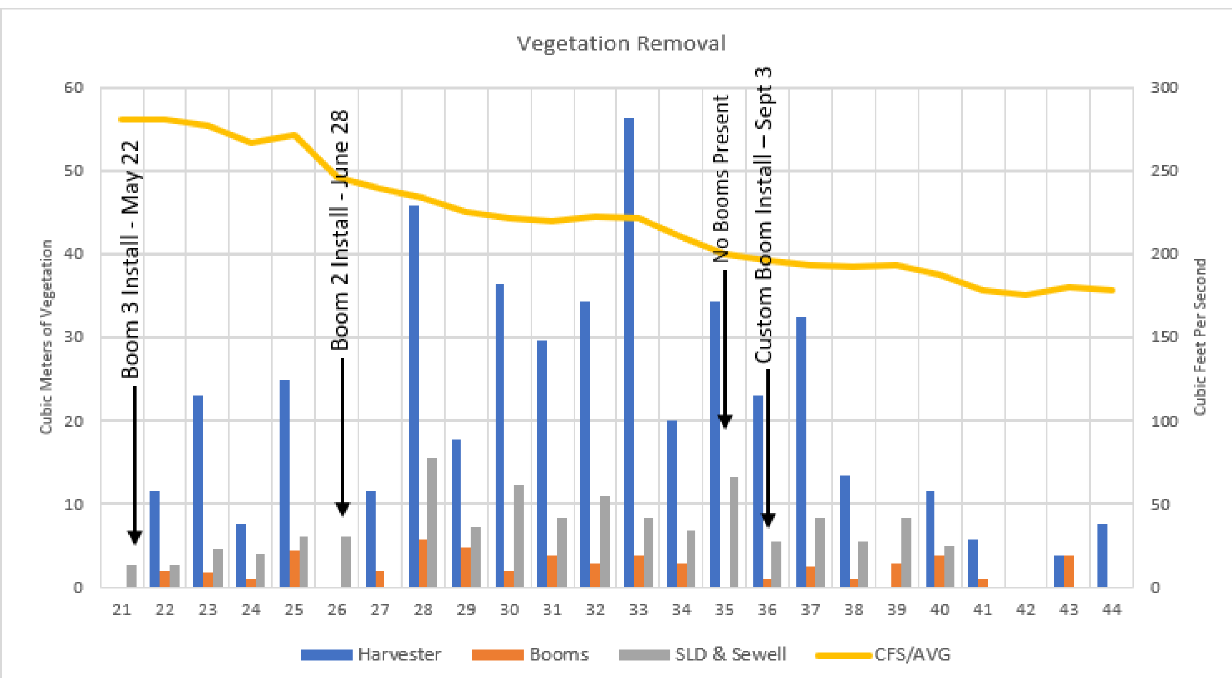


Figure 7. Collection data for harvester activity, boom collection events, and vegetation mat removal from Spring Lake Dam and Sewell Reaches. Includes flow data for the river in CFS weekly average. Data shown in Appendix A3.

The amount of vegetation mat removal associated with the booms did not appear to materially reduce either the size of the crew or time required to remove downstream vegetation mats. The increased cost of actual harvester operations to remove vegetation mats from the booms in addition to the time required for boom maintenance by divers do not appear to provide a substantive cost-benefit to vegetation mat removal within downstream reaches of the river. A significant factor to the buildup of vegetation mats within the river is related to the seasonal shift in vegetation growth within the lake and the morphological shift in TWR towards sexual reproduction during the summer months. During this period, TWR produces a woodier stalk and becomes more emergent. This results in mature stands collecting more floating vegetation rather than other periods where floating vegetation can pass over the top of the TWR. The boom assessment took place during the period when vegetation mat buildup would be at its worst due to this seasonal shift in which TWR is emergent. That is attributed as one mechanism where even after the boom installation, vegetation mat collection volumes showed an increasing trend in removal volumes.

It is possible that the booms would have more of an effect on downstream vegetation mat removal efforts in the winter months. However, given the required time and cost associated with boom maintenance and harvester operations, these costs likely outweigh any measurable benefit to reducing downstream vegetation mat removal time and cost. The high aquatic vegetation production during spring through fall is expected to continue to be problematic given the observed accumulation of aquatic vegetation mats on TWR, especially given the increasing TWR aerial coverages being implemented as part of the EAHCP.

It is also noted that having the booms installed in Spring Lake with the associated buildup of vegetation mat on the booms and the physical footprint of the booms themselves, is not esthetically pleasing to the glass-bottom-boat tours (see Appendix A10). The booms also result in the presence of denuded areas directly in front of the booms that represent modified natural habitat conditions (see Appendix A11 & A12). Finally, as noted, the added time required for inspections and maintenance of the booms and associated increased costs in harvester operations do not appear to offset measurable gains in the reduction of time and effort for vegetation mat removal in downstream reaches.

Recommendations

Due to the repair efforts on Spring Lake Dam, the option of installing a third boom, at an opposing location to where the two booms were installed, was never tested. Having a boom on the opposing side would allow for the booms to cover more of the main flow path in the lake and would be in a position to capture additional vegetation that is diverted around the other booms as they begin to fill. This could be investigated in the future; however, this downstream location has limited access for the harvester which would need to be critically assessed. Testing the booms in Spring Lake did not prove to be effective at decreasing the downstream time and effort for vegetation mat removal in the river.

Appendix A

Appendix A1. The harvester emptying out temporary boom 3 after additional anchor weights were installed and subsequent leftover vegetation due to shallow water inhibiting the harvester's access.

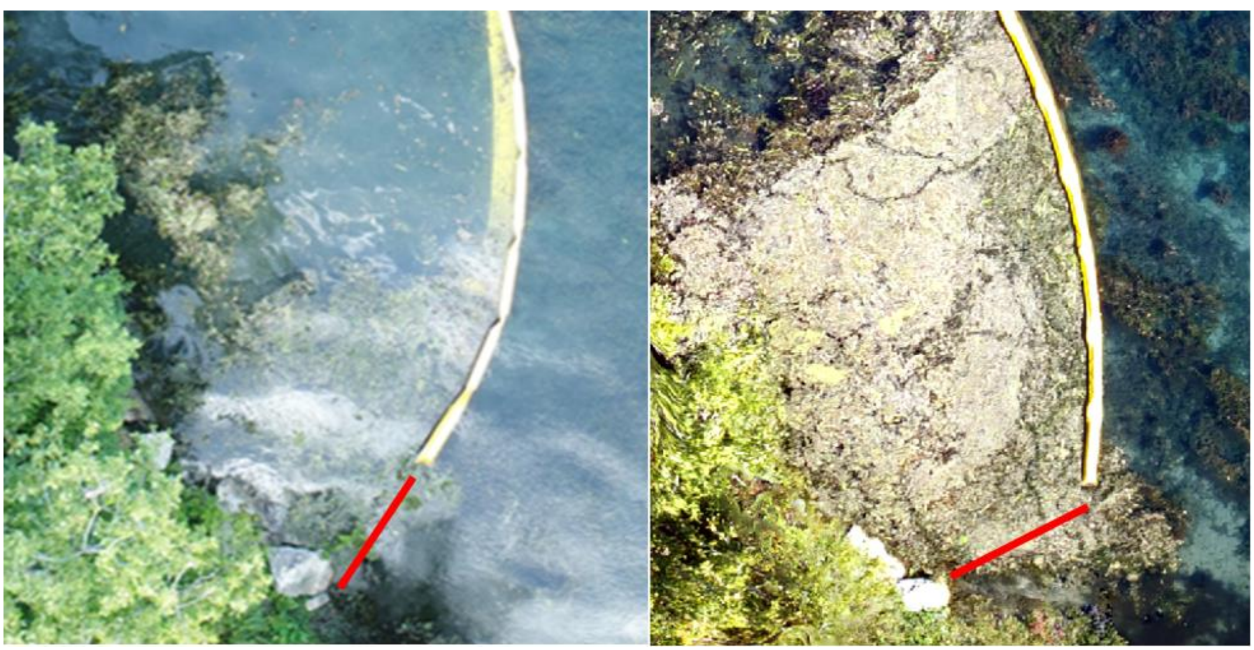
Appendix A2. Shows the gap between the skirt and the lakebed that allowed for vegetation to flow underneath the boom and escape collection.

Week	Date Range	Harvester (m^3)	Booms (m^3)	HW & Sewell (m^3)	CFS/AVG	Boom Collection Events
21	May 19 - May 25	0.00	0.00	2.75	281.25	0
22	May 26 - June 1	11.47	1.91	2.75	280.43	1
23	June 2 - June 8	22.94	1.67	4.52	277.14	3
24	June 9 - June 15	7.65	0.96	4.02	267.00	1
25	June 16 - June 22	24.85	4.30	6.03	271.43	4
26	June 23 - June 29	0.00	0.00	6.03	245.57	0
27	June 30 - July 6	11.47	1.91	0.00	239.57	2
28	July 7 - July 13	45.87	5.73	15.58	233.57	4
29	July 14 - July 20	17.68	4.78	7.15	225.14	2
30	July 21 - July 27	36.32	1.91	12.38	221.43	2
31	July 28 - Aug 3	29.63	3.82	8.25	219.29	3
32	Aug 4 - Aug 10	34.41	2.87	11.00	222.00	3
33	Aug 11 - Aug 17	56.40	3.83	8.25	221.29	3
34	Aug 18 - Aug 24	20.07	2.87	6.88	210.14	2
35	Aug 25 - Aug 31	34.41	0.00	13.20	200.00	0
36	Sept 1 - Sept 7	22.95	0.96	5.50	195.86	1
37	Sept 8 - Sept 14	32.49	2.40	8.25	193.57	3
38	Sept 15 - Sept 21	13.38	0.96	5.50	192.71	1
39	Sept 22 - Sept 28	0.00	2.87	8.25	193.57	1
40	Sept 29 - Oct 5	11.47	3.82	4.95	187.29	1
41	Oct 6 - Oct 12	5.73	0.96	0.00	177.86	1
42	Oct 13 - Oct 19	0.00	0.00	0.00	175.71	0
43	Oct 20 - Oct 26	3.82	3.82	0.00	180.14	1
44	Oct 27 - Nov 2	7.65	0.00	0.00	178.33	0
Total		**450.65**	**52.36**	**141.23**		**39**
Average		**19.26**	**2.28**	**6.14**		**1.7**

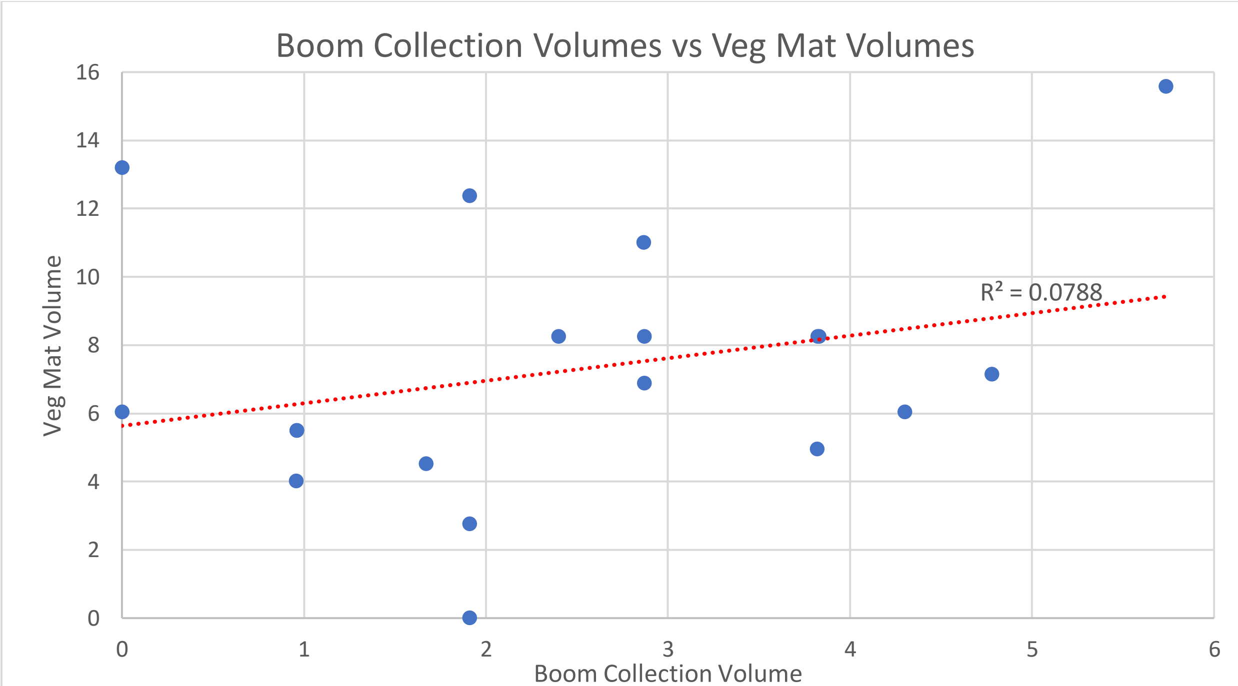
Appendix A3. Collection data for harvester activity, boom collection events, and veg mat removal from Spring Lake Dam and Sewell Reaches used in Figure 7 and Appendix A8, all in cubic meters. Includes flow data for the river in CFS weekly average and number of boom collection events per week.

Appendix A4. Vegetation buildup on the anchor cables and outside end of boom 2.

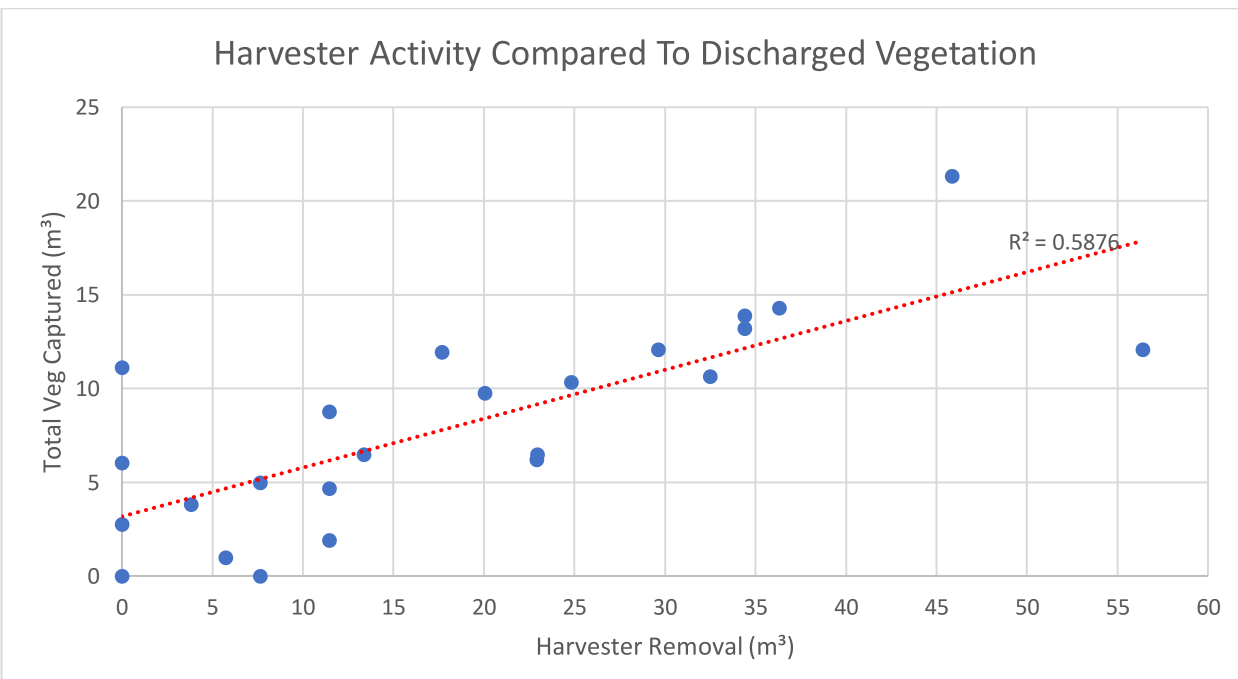
Appendix A5. Setup for initial vegetation collection in Spring Lake Dam Reach below the western spillway.



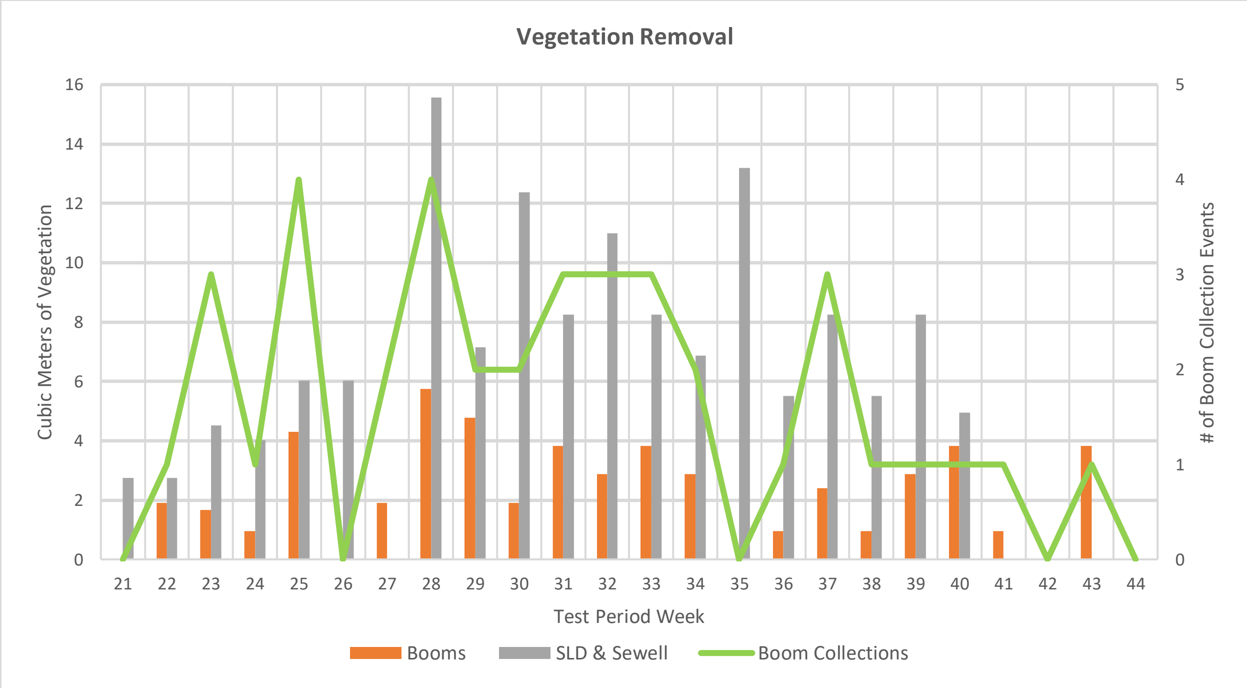
Appendix A6. Red line shows location of t-posts installation. Temporary boom layout on left. Custom boom layout on right.



Appendix A7. Comparison between the boom collection volumes and the veg mat removal volumes, measured in cubic meters per week.

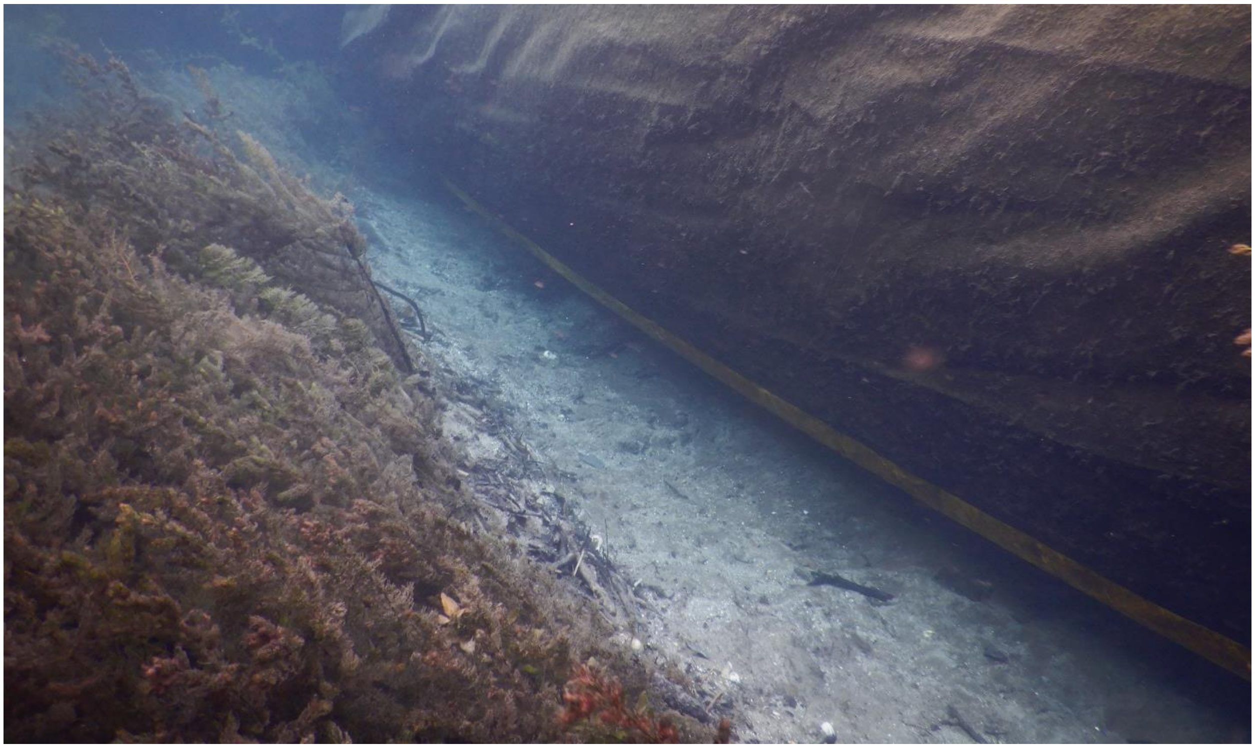


Appendix A8. Linear regression comparison between the harvester removal quantities within the lake (x-axis) and the combined boom collection and veg mat removal amounts (y-axis). All amounts are in cubic meters per week.

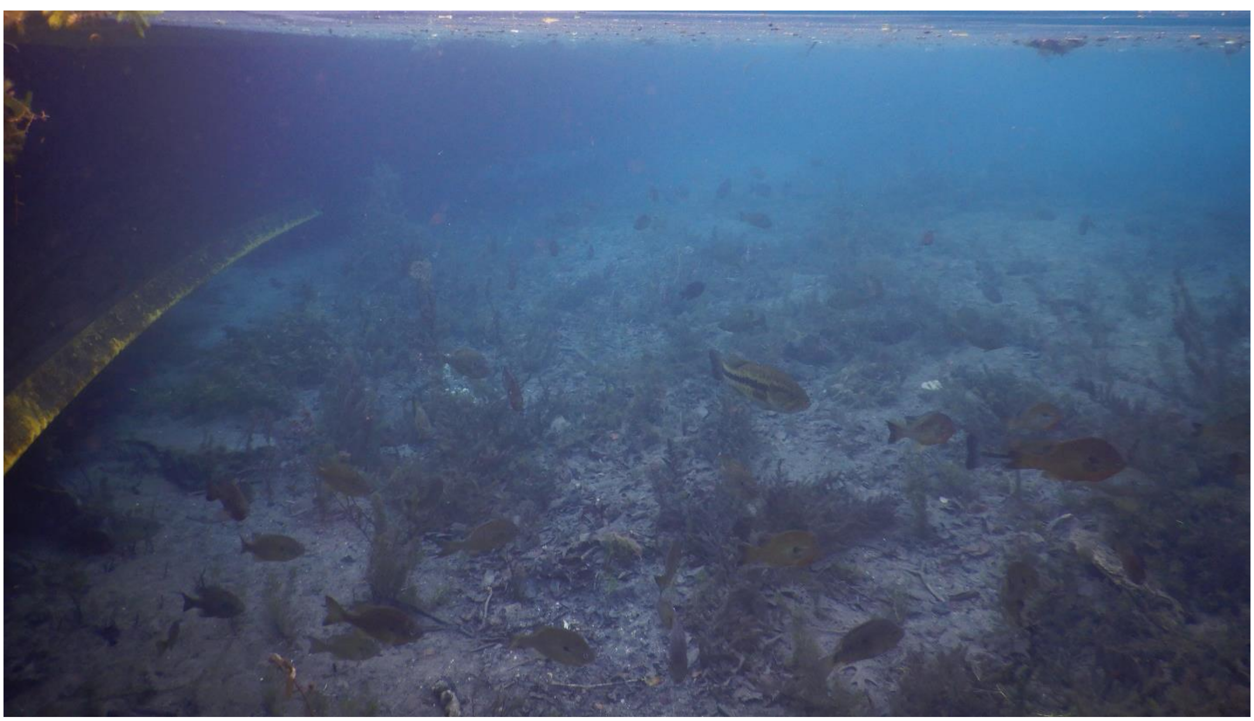


Appendix A9. Collection data comparing the volume collected from the booms and veg mat removal from designated collection area per week. X-axis is the test period week and y-axis is the volume of vegetation removed per week (see Appendix A3). Includes the number of boom collection events per week shown with the green line.

Appendix A10. Temporary boom 3 setup near full capacity showing what it looks like before harvester collection.



Appendix A11. Custom boom 3 before removal showing the buildup of sediment behind the boom due to harvester activity pushing excess water under the boom during removal efforts.



Appendix A12. Area in front of custom boom 3 before removal showing the denuded area due to floating vegetation accumulation that's typical overhead and harvester activity from removal efforts.