Wave Damage – Part 2
Natural Wind vs Wake-Sport Boats

15 Mar 2025

Prepared by Grant Miller, President, Sacheen Lake Association

How to Participate in the Zoom Meeting

- I will be sharing my screen with you to display the presentation
- Be sure that the presentation is large on your screen
- Please put your mic on mute for the meeting
  - Your choice to use your camera or not
- During the presentation I will be focusing on the slides and cannot see raised hands nor will I be able to concentrate on chat notes
- If you want to talk, unmute your mic and interrupt at an appropriate time (“excuse me, Grant, I have a comment/question”)
  - Be sure I have your attention before you speak so we don’t talk over each other
- After our joint discussion, mute your mic again
- For ease of execution, please do not interject into an ongoing discussion

Thank you!

Why is the SLA Involved?

This is an exact copy of slide 5 from the Oct 2024 presentation, except the highlight box

- SLA By-laws:
  - SLA is a benevolent, non-profit business registered with the WA Secretary of State
  - We are required to follow our By-laws
- Our By-laws Mission Statement:
  - ***The purpose of the Sacheen Lake Association is to advocate for the conservation as well as safe and environmentally sustainable use of Sacheen Lake and surrounding ecosystems, while promoting a strong sense of rural community.***
- Conservation, environmentally sustainable use:
  - Shorelines are being damaged by large wakes
  - Studies show that bottom sediment is disturbed by downward pointed props causing harmful release of phosphorus which causes algae growth which cuts off oxygen and sun
- Safe use of Sacheen:
  - Large wakes create an unsafe environment to property and people as is demonstrated by community responses to our survey and damage photos received this year
- Strong sense of rural community:
  - Our rural community is suffering the financial, time, and effort impacts of repairing damage caused by artificially created large wake rather than enjoying Sacheen Lake

This slide is similar to slide 3 of the Oct 2024 presentation. It was created after careful consideration of some community members' comments

Contrary to Some People's Thoughts …

- The SLA has received emails from community members that believe that I and/or the SLA Board have an agenda. I think they believe that agenda is to get wake boat sports banned on the lake
- The SLA Board has no intention of making any decisions for the community
- The SLA Board is trying to help the community get informed, and as needed organized, so they can make a decision on what to do, if anything
  - The SLA Board created a laundry list of what-to-do options that are contained in the Oct 2024 presentation
  - That laundry list was briefly reviewed and the audience at the time recommended doing only education
- ***Today's presentation is more educational information created as a direct result of comments from the Oct 2024 meeting***

The Plan

This slide was not in your version of the presentation. It was created after careful consideration of some community members' comments

- One of the SLA By-laws Goals is:
  - "Promote education, involvement, and SLA membership of and by the local rural community for enduring SLA Mission Statement advocacy and a strong sense of community."
- The following is what the SLA Board has agreed to do:
  - Educate the community on the technical research findings regarding wake-sport boat waves. Part 1 is completed; Part 2, the last part, is today
  - Execute an anonymous survey to allow the community to provide input on what has happened to their property, what they believe is the cause of the damage, and what they want to do about it.
    - A website link to the survey will be released soon via email and postcards sent via USPS
  - Inform the community as to the results of the survey at the SLA Annual Meeting on 14 June 2025
  - Should the community want to do something after the survey*, the SLA Board has agreed to help facilitate the community

* The SLA Board will continue to fulfill our By-laws documented goal to educate the community on lake issues regardless of the outcome of this process

Purpose and How Accomplished

- To address comments made by the audience at the October 2024 SLA Board Wake Damage presentation regarding wind damage as compared to wake-sport boat wave damage
- Specifically, to compare the energy imparted by wake-sport boats as compared to wind in a real-world scenario on Sacheen Lake
- A 2015 study on wake-sport boat wave energy that analyzes wind wave energy will be explained and then used as the basis for analysis relating to Sacheen Lake

Warning?

- This presentation contains a lot of technical data
- There is no expectation that the audience understands the math behind the data!!!
- Bottom line is presented up front for those that don’t care about the “how to reach the conclusions” portion of the presentation
  - But I encourage you to stay anyway to hear any discussions that may occur
- Purpose of the technical details and presentation approach:
  - Illustrate the validity of the study by comparison to the two other studies the SLA presented in October 2024
  - To accept that the analysis approach is equally applied to measured boat-wave data and analytical wind data
  - To illustrate that the data and curves presented on wave and wind energy can be used for real-world conditions on Sacheen Lake
- Feel free to ask questions!

Topics

- Bottom Line Up Front
- Summary of Oct 2024 Wave Damage Presentation
- Wake-sport Boat and Wind Study
    - Study Setup and Measured Data
    - Study Analysis Approach and Findings
    - Study Analysis on Wind Waves
    - Assessment of the Conclusions of the Study
- Application of the Analysis and Conclusions for Sacheen Lake
- Wrap Up
- Addendum / Backup Slides

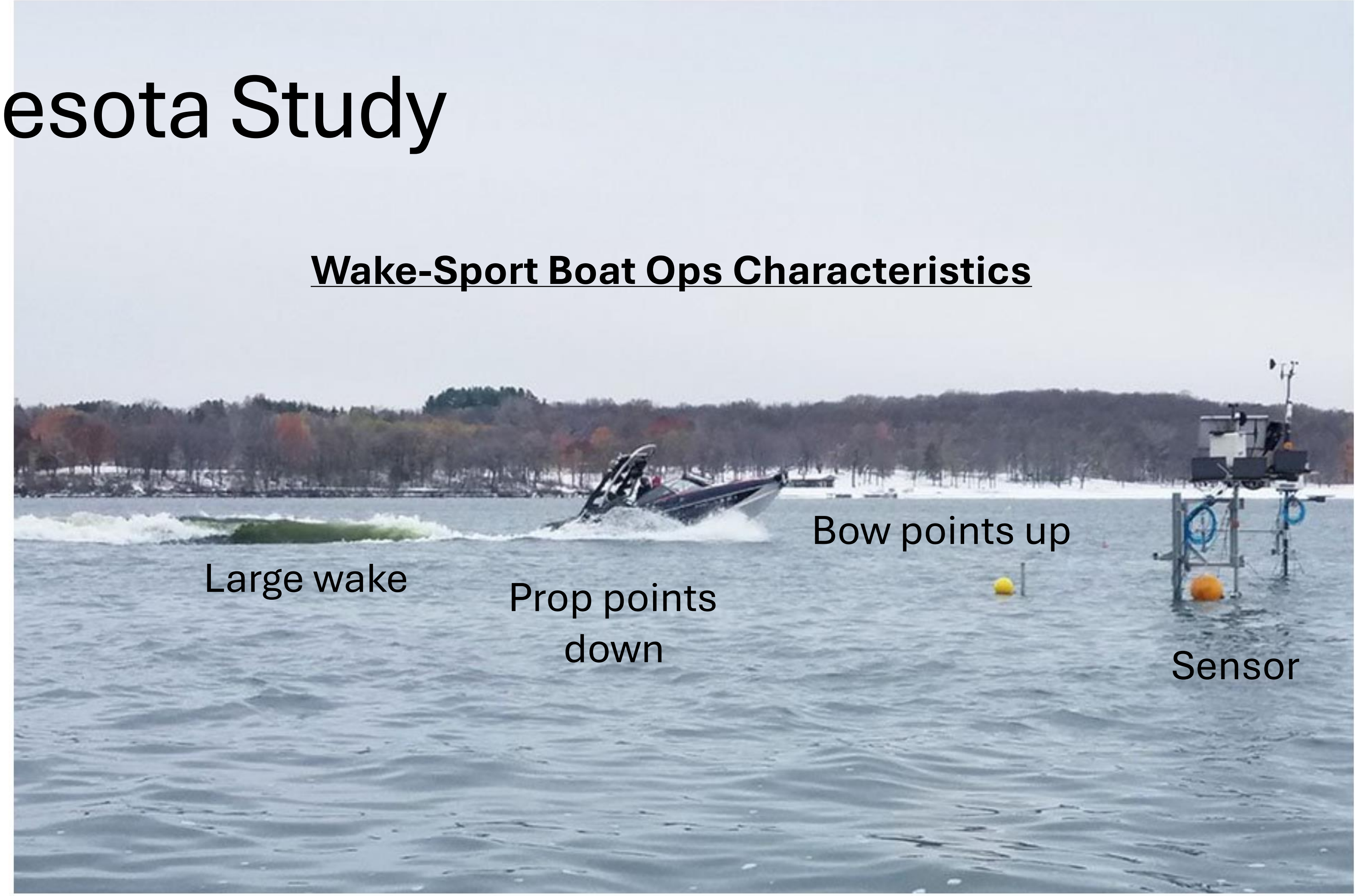
Bottom Line Up Front

- New study's measured wake-sport boat wave data is similar to the two studies presented in October 2024
  - Wake-sport boats in wakeboard and surf mode create much more energy than recreational boats or wake-sport boats in cruise mode (no ballast)
  - Per the study, an additional 220 ft (shallow water) to 320 ft (deep water) of distance from shore is needed for surf mode waves to dissipate to that of cruise mode at 110 ft from shore. These numbers are from curves of smoothed data points; the data points themselves for deep water, specifically, show that further distances are needed
- Conclusions regarding wind vs wake-sport boats in the study are misleading; real-world conditions, especially for smaller lakes, are **not** taken into account
  - Wind strength and fetch of the study are **not** comparable to Sacheen Lake
  - The study uses a smoothing technique in comparing imparted boat and wind wave energies that reduces the real-world higher, short-term power impact of boat waves
  - Breaking / tensile strength of docks, etc., is **not** taken into account in how they compare waves from wind vs waves from boats
- An analysis of Sacheen Lake's real-world conditions illustrates that wind waves are much less likely to cause damage to physical property
  - Shoreline impacts fall into a different category of how wind vs boat waves affect the shoreline; gradual wear and tear of shoreline may / may not fall into a breaking / tensile strength category
  - It is common sense (and my experience) that larger waves can pick up debris on the lake's bottom and use this material as an additional wear and tear force that small wind waves cannot

Summary of Oct 2024 Wave Damage Presentation

U. of Minnesota Study

- Photo illustrates measurement equipment of the study
- Caption discusses what they did
  - Recreation boats
  - Wake-sport boats
- https://cse.umn.edu/college/news/umn-researchers-study-waves-created-recreational-boats
- Study results: Need an additional ~500 ft for the wake-sport boat wake to dissipate to the level of the waves of the recreational boat in the test



Researchers from the University of Minnesota St. Anthony Falls Laboratory carefully measured the maximum height, total energy, and maximum power of the waves from wakes produced by four recreational boats—two wakesurf boats and two more typical recreational boats. They also measured how the wake waves changed as they moved away from the boats and toward shore. Photo credit: Healthy Waters Initiative, University of Minnesota

U of M: Wave Packet Energy

(Chart Not Included in Oct 2024 Presentation)

- The mast and pad data points are the sensors
- Distances are distance from the sensors
- Boats were:
  - 2004 Larson LXI 210 (recreation only)
  - 2004 Malibu Response LX (recreation with hydrofoil and aftermarket wave shaper)
  - Malibu VLX and MXZ (ballast, hydrofoil and wave shaper)
- At 100’, the wake-sport boat energy is 3.5 times more than the recreational boats
- At 100m (328ft), the wakesurf boat energy (~2670 J/m) is ~ 2x energy of the recreational boats (1330 J/m)
- At ~ 425 ft, the wakesurf boat energy is equal to the energy of the recreational boat at 100 ft (additional 325 ft for energy dissipation)
  - Note: The prior 500 ft was from text of the report; which appears different from this generalized plot of the field data. But the prior statement <u>does</u> match the data points displayed!

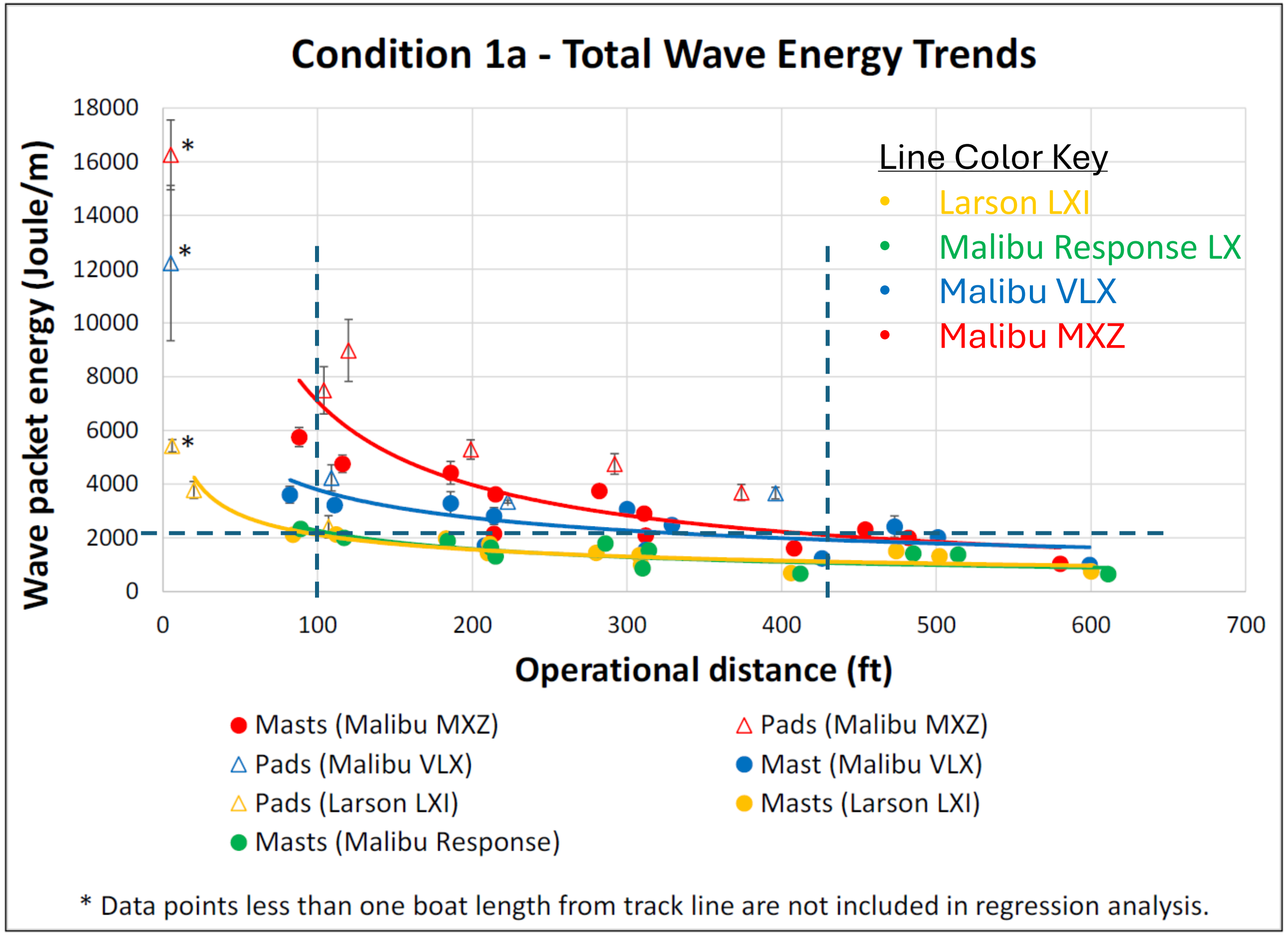


Figure 18. Condition 1a trendlines for the four test boats showing total wave energy over operational distance.

The dashed lines above illustrate where the Malibu MXZ energy equals the Larson LXI energy at 100 ft

Canadian Study: Turbulent Kinetic Energy (TKE) Data

- "The turbulent kinetic energy (TKE "turbulent kinetic energy") contained in a wave (created by a boat or otherwise) can be calculated by knowing the speed dimension as it passes, according to the equation: $TKE = \frac{1}{2}\left(\overline{x^2} + \overline{y^2} + \overline{z^2}\right)$,

  where z, y and z are the speeds of the micro-turbulence measured in three dimensions (Wist 2004)."

- **At 100m (328 ft), the TKE of wake-sport boat in wakesurf mode ~= 2 x TKE of the same wake-sport boat in travel mode (empty ballast)**

- **The U of M study at 100m illustrates the same 2X as this study, therefore, it is quite likely extrapolating this data to 100ft produces the same 3.5 factor as the U of M study**

- **Reference:** Project Evaluation of the Impact of Waves Created by Wake Boats on the Shores of the Lakes Memphremagog and Lovering, by Sara Mercier-Blais and Yves Prairie June 2014

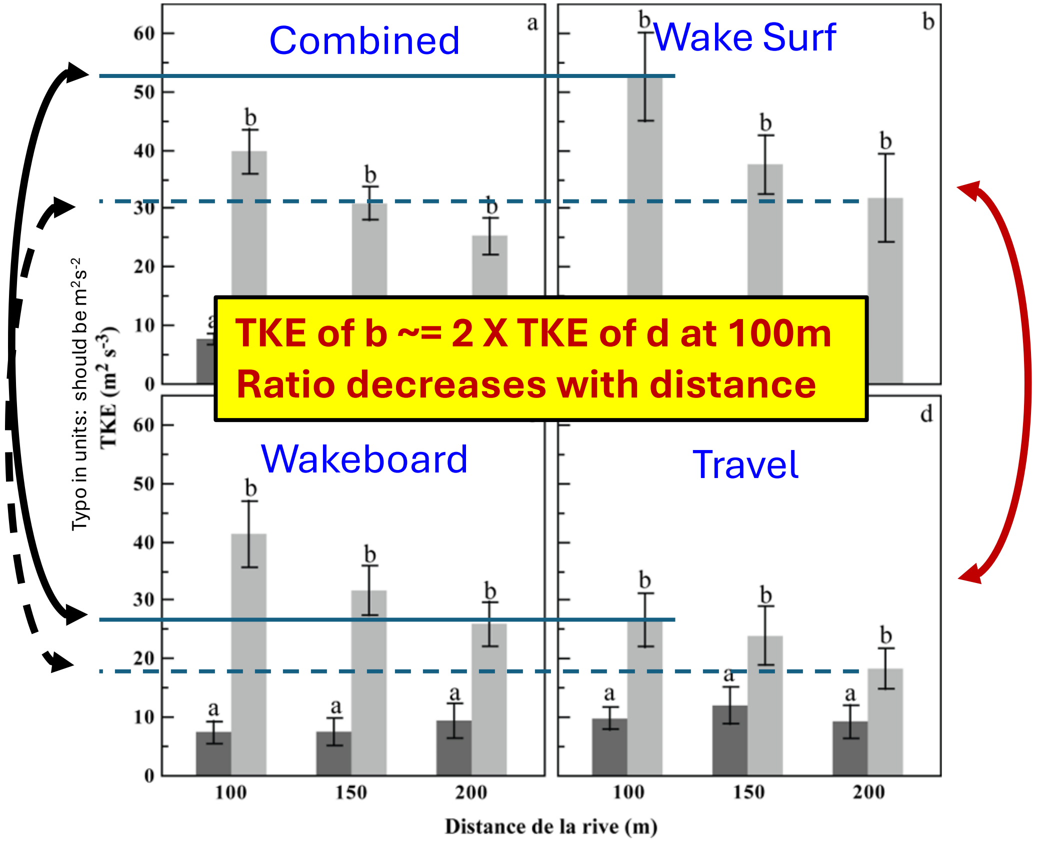


Figure 5. Energy (TKE) present in normal waves (dark gray) and that present in the waves following the passage of a wake boat 100, 150 and 200m from the shore, and the type of transition from boat (a: for all types of passage; b: 10 miles/h; c: 20 miles/h; d: 30miles/h).

a. Normal Conditions: No passing boat (dark bars)
b. Wake Surf: Ballast on one side only filled
c. Wakeboard: Both ballast tanks filled
d. Travel: Empty ballast tanks

Canadian Study: Shoreline Slope Impact of Wave Energy

- Two shoreline slope values tested
- Slope did not have a <u>significant</u> impact on TKE of wake-sport boat wake (TKE delta = 7 m^2/s^2 or 26%)
  - Steeper slope wave had larger TKE
- **TKE wake boat =**
  - **4.4 x TKE wind for steep shore**
  - **3.9 X TKE wind for not steep shore ("coastal slope")**
- Ref: same as prior slide
  - Report did not distinguish the operational mode of the wake boat (travel, wakeboard, surfing) for this chart

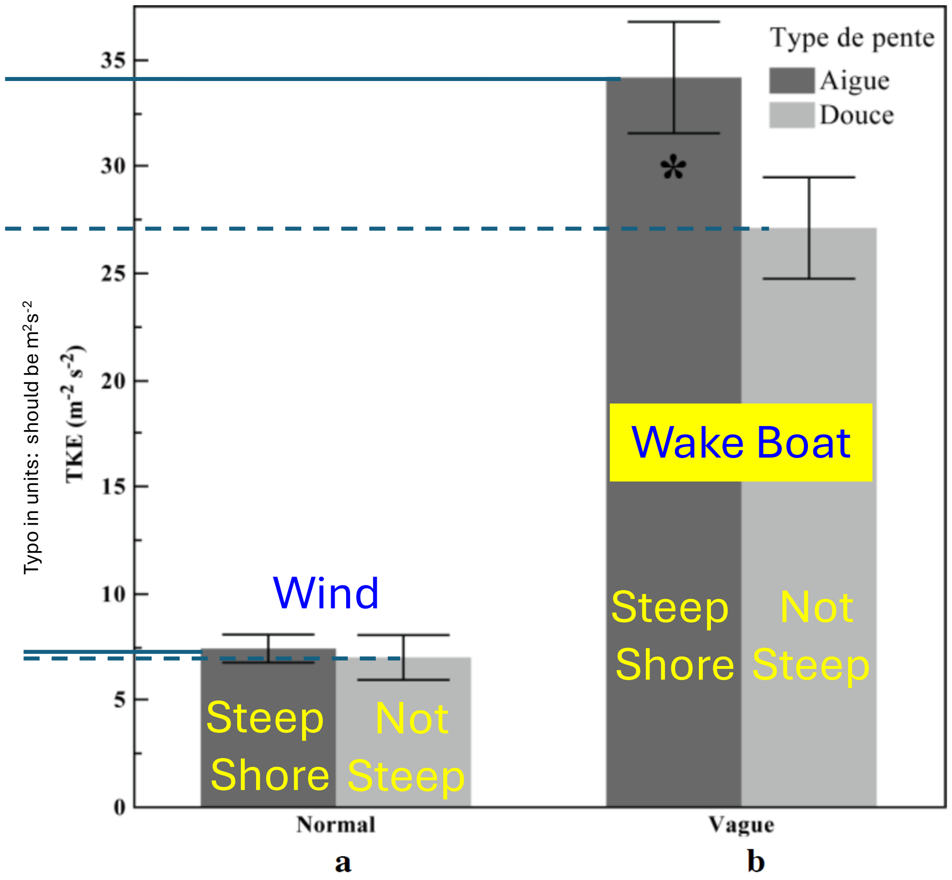
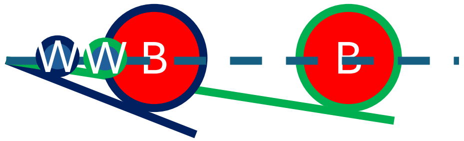


Figure 11. Energy (TKE) that reached the shore between sites with sloping coastline of acute (dark gray), coastal slope (pale gray), for normal waves (a) and that from a wake boat (b).
Note: The asterisk (*) represents a significant increase ($p < 0.05$).

Why the difference in gaps for the boat vs the wind?



Boat (B) and Wind (W) waves encountering the bottom as depicted in the bar chart of Figure 11.; for the boat, more energy dissipation occurs before hitting the shore in shallow vs deep as compared to shallow vs deep for the smaller wind waves.

Canadian Study: Summary of Data Analysis

- Wake-sport boats in wakeboard and surf mode create significantly more turbulent kinetic energy (TKE) in their wake than the same boat without any ballast loading ("travel" mode)
  - At 100m (328 ft): TKEsurf = 2 x TKEtravel (same results as U of M)
  - At 200m (656 ft): TKEsurf = 1.7 x TKEtravel
- Waves from the wake-sport boat had significantly more energy that that of normal (wind*) waves
  - TKEwake-boat = 4.4 x TKEwind for steep (acute) shoreline
  - TKEwake-boat = 3.9 x TKEwind for not steep (coastal) shoreline

- **Reference:** Project Evaluation of the Impact of Waves Created by Wake Boats on the Shores of the Lakes Memphremagog and Lovering, by Sara Mercier-Blais and Yves Prairie June 2014

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* The study did not provide details on the wind speed. Longest fetch is ~ 650 ft on Lake Memphremagog and < 2 mi on Lake Lovering; it is unclear how the sensors and prevailing winds align with these fetches. This wind data may not be comparable to the wind analysis of the boat and wind comparison study discussed later herein (i.e., not persistent enough and not a long enough fetch)

2023 Annual Meeting - Shoreline Erosion Survey Response

- As of 5/29/23, 19 community members responded to the survey, one member responded to the presence of the survey
- Of the 19 responses
  - 10 responded with damage to their property (one or more of): dock, pilings, anchor chains, broken ropes, landings, dock sections came apart, tie downs ripped from the dock, retaining /sea walls, broken items on the dock, reduced/eliminated ability to moor boat to dock, lost trees on shoreline
    - One person replied a cost of $26,000 for dock and anchor replacement and a rock breakwater
    - Many did repairs on their own
    - Some have repairs to do still with costs expected to be $20,000 or more
  - 11 responded with shoreline erosion. One noted trees lost due to erosion
    - One person reported 6' of loss and a cost of $18,000 to stabilize the shoreline (a neighbor paid the same for repairs)
  - 2 responded with people being knocked off their feet on their dock (multiple times), being thrown into the water. No injuries reported!
    - Almost falling (1)
  - 4 responded with no damage or injury
    - 1 of these indicated they do not tie their boats to the dock anymore when wake boats are running for fear of damage
  - Multiple people commented that water activities are curtailed by wake boat activity due to safety concerns (e.g., kids swimming/floating next to a dock)
    - Fear of injury to their kids/grandkids, or kids afraid to be on the dock when wake boats are present

2023 Annual Meeting - Shoreline Erosion Survey Results

- Survey results:
  - 1. Property damage or personal injury: See prior slide
  - 2. Property direction: Damage occurred in all shoreline facing directions and throughout most of the lake. Implies that damage is not caused by natural prevailing winds
  - 3. Area: Damage is greatest on the 35 mph sections of the lake. One reported damage in the Narrows (no wake zone)
  - 4. Cause: wake/surf boat wake is sited as the primary cause (14 of 19 inputs)
  - 5. Repairs: Dock repairs/replaced, replaced anchor chain/rope, breakwater built, beefed up dock landing, replaced dock to landing attachment, repositioned dock anchor, replaced anchor chain. Still need to repair: 3
  - 6. Cost ranges from hundreds to multiple 10's of thousands of dollars. One cited $450 for POC permit. Total costs of all repairs reported & projected repairs is about $83K and does not include 2 locations that have not yet done repair work
  - 7. Preemptive steps: don't use their dock or don't use it or the shoreline when large waves present, placed or already have rocks or logs as shoreline breaks. About 1/2 took no action; at least 2 investigating installing retaining walls

2024 Damage Reports

- Residents have independently been sending emails of damage
  - Broken docks
  - Moved docks
  - Washed out shorelines
  - Damaged retaining walls
- Photos available in Addendum

Wake-sport Boat and Wind Study

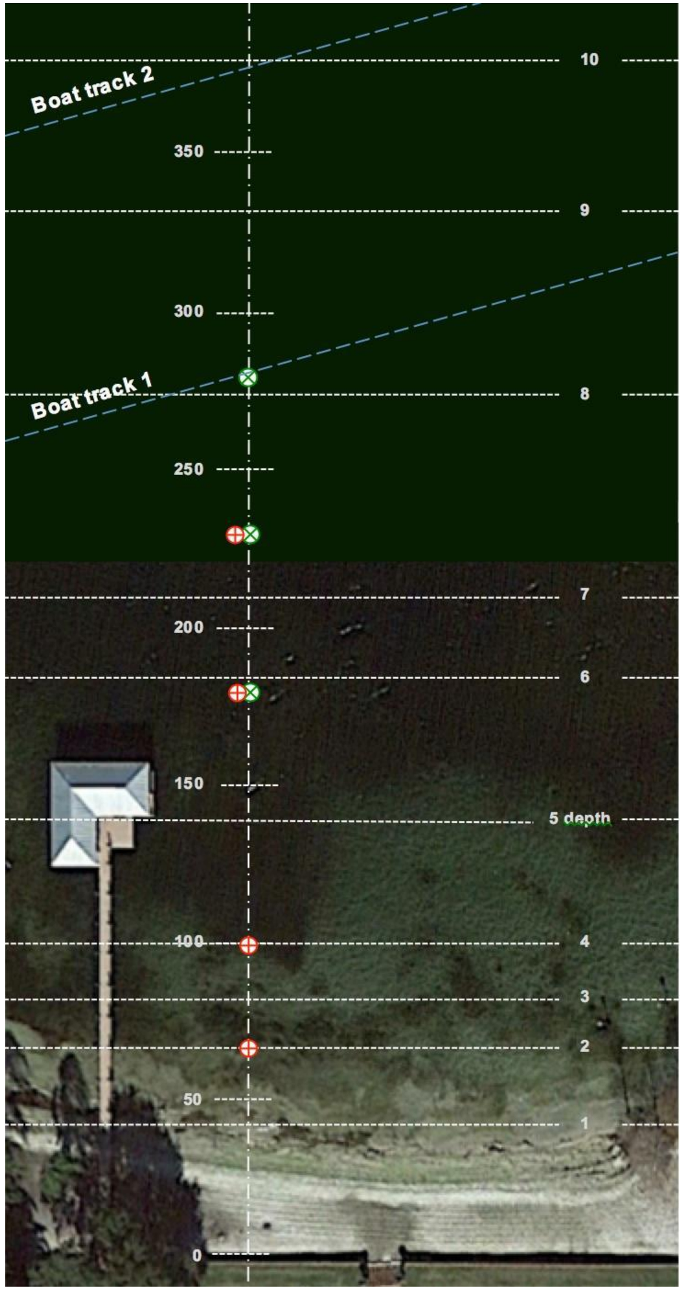
Ref:

Characterization of Wake-Sport Wakes and their Potential Impact on Shorelines,

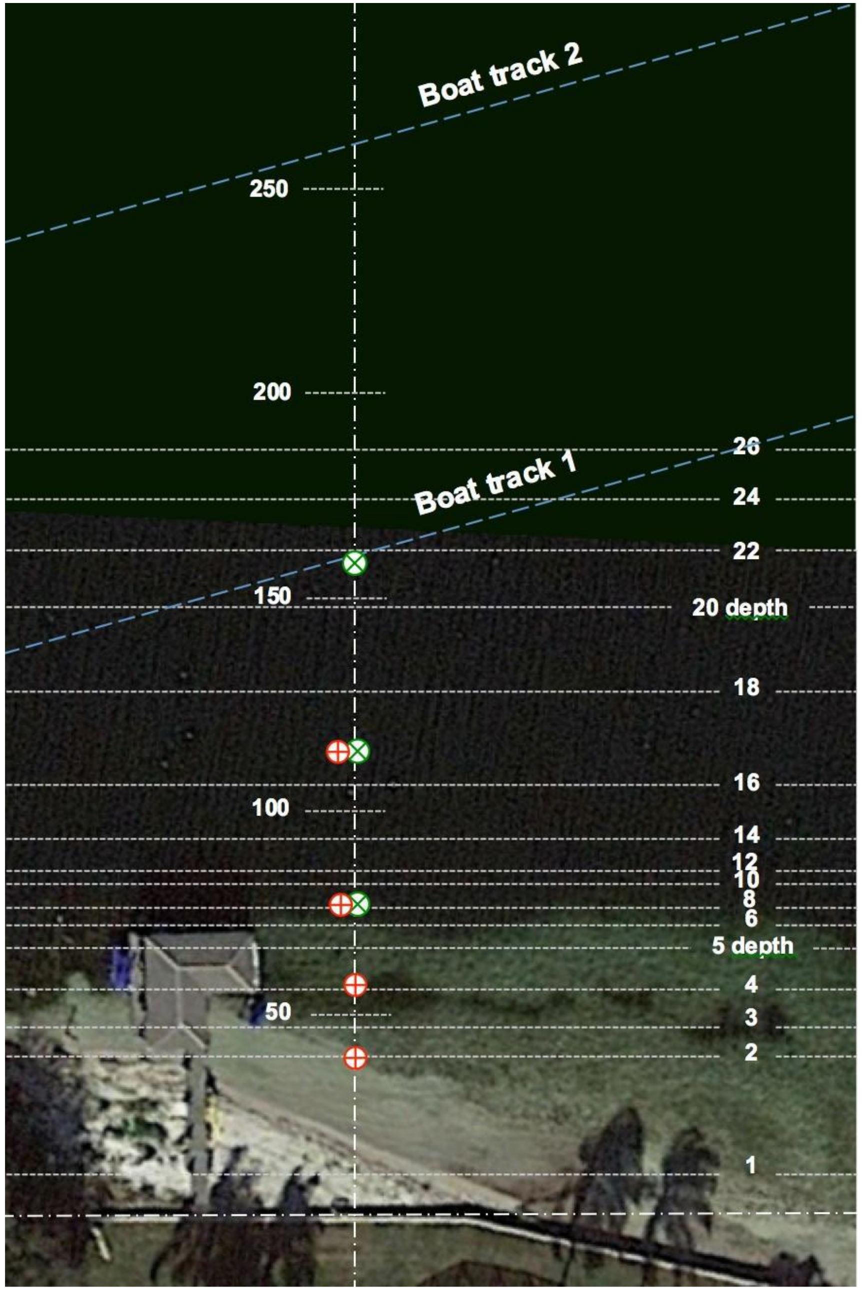
WATER SPORTS INDUSTRY ASSOCIATION (WSIA), November 2015 (Draft Rev 2 (or 11???))

WSIA Study Setup

- Two test setups: shallow water, deep water
- One boat in 3 modes of ops:
  - Cruising: No ballast added
  - Wakeboard: Max ballast
  - Wakesurf: Additional ballast
- Five sensor locations each
- Two sensor types
  - Correlation / calibration of least sensitive (pressure sensor) to most sensitive (capacitance wave probe) due to overlap at two locations



Shallow Test Range



Deep Test Range

Test Runs

Ballast Weight Added

Cruise -	0 lbs
Wakeboard -	2,850 lbs
Wakesurf -	4,250 lbs

- 42 test conditions, 94 runs covering all 42 test conditions (mode, speed, track from sensor #1)
- Resultant test data is expressed as a function of distance from the closest sensor
  - Sensor #1 to: Track 1 = 10’, Track 2 =110’, Track 3 = 210’
  - See tracks relative to depth below
  - Top scale is distance from shoreline
  - Sensor distances from shore are shown

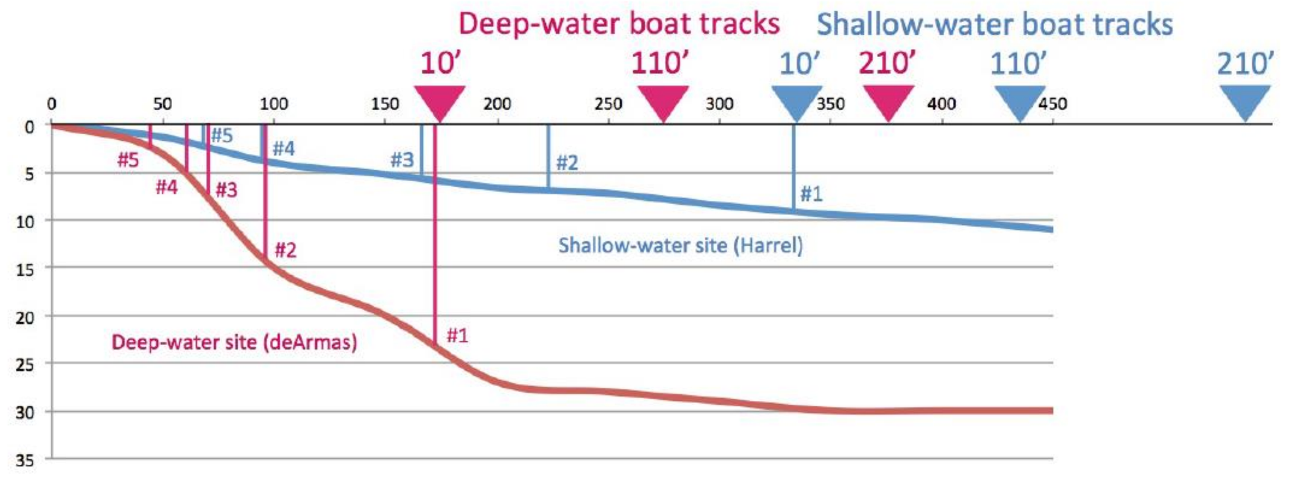


Figure 2. Depths, sensor locations, and boat tracks for the two test venues.

Length overall:	23’ / 7.01 m
Max beam:	102” / 2.59 m
Light displacement:	5,900 lbs / 2,676 kg

Figure 9. The Nautique G23 test boat in wakesurf condition.

Mode	Speed (mph)	Distance from Station #1 (ft)		
Cruising	20	10	110	210
	25	10	110	210
	30	10	110	210
Wakeboard	21.2	10	110	210
	22.2	10	110	210
	23.2	10	110	210
Wakesurf port	10	10	110	210
	11	10	110	210
	11.5	10	110	210
	12	10	110	210
Wakesurf starboard	10	10	110	210
	11	10	110	210
	11.5	10	110	210
	12	10	110	210

Table 3. The test matrix for both the shallow and deep-water test sites.

Test Results – Cruise Vs Wakeboard, Shallow for Track 1 (10’ from sensor #1)

- Graphs illustrated with same vertical scale
- Height illustrated is trough to crest height
- Note that the further the boat is from the sensor, the more elongated in time the wave structure becomes and the smaller the maximum wave height
- Almost all wave height plots illustrate that the waves fully pass each of the sensors within 60 seconds

Each wave height plot recenters at the 0 value; the scale across wave plots is the same

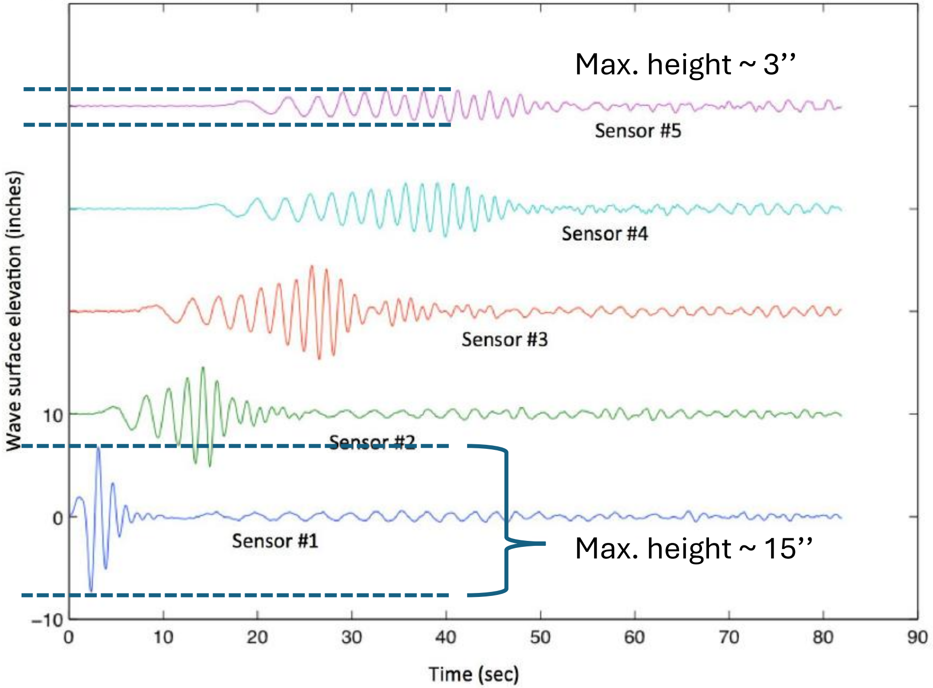


Figure 10. Shallow-water Run #6 - Cruising, 25 mph, 10’ standoff.

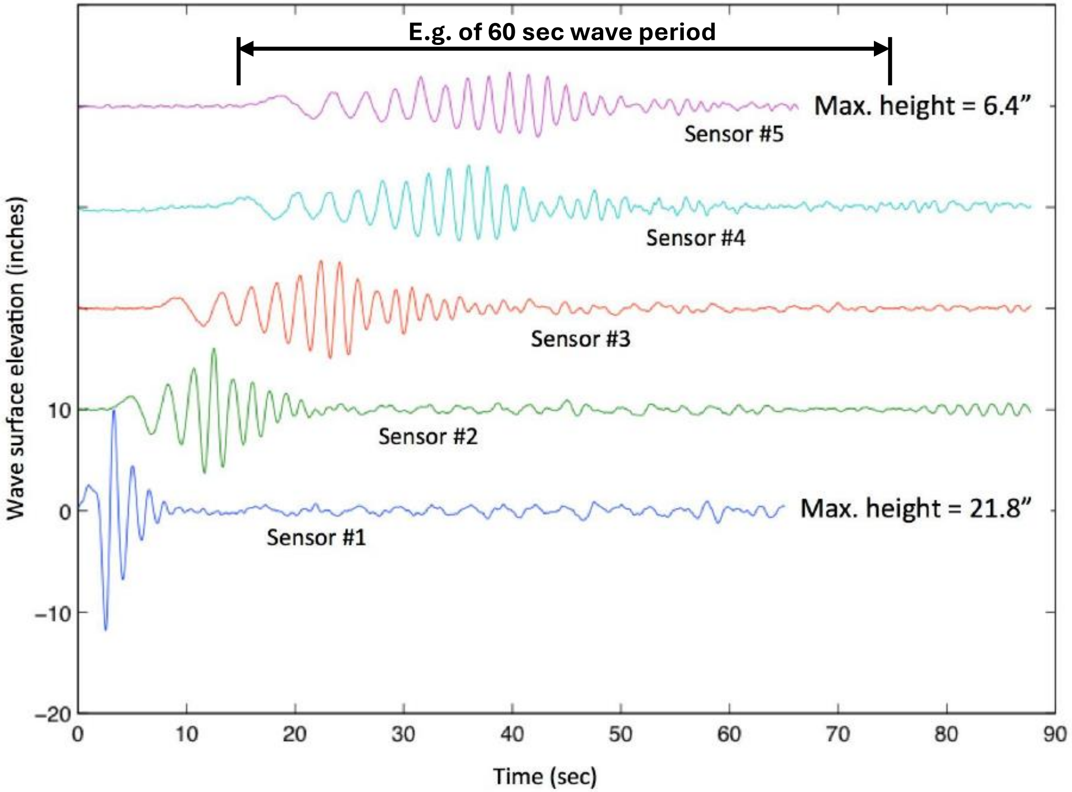


Figure 11. Shallow-water Run #15 - Wakeboarding, 22.2 mph, 10’ standoff.

- Max wave height of wakesurfing is 21.8” compared to 15” for cruising

Test Results – Cruise Vs Wakesurf (port), Shallow for Track 1 (10’ from sensor #1)

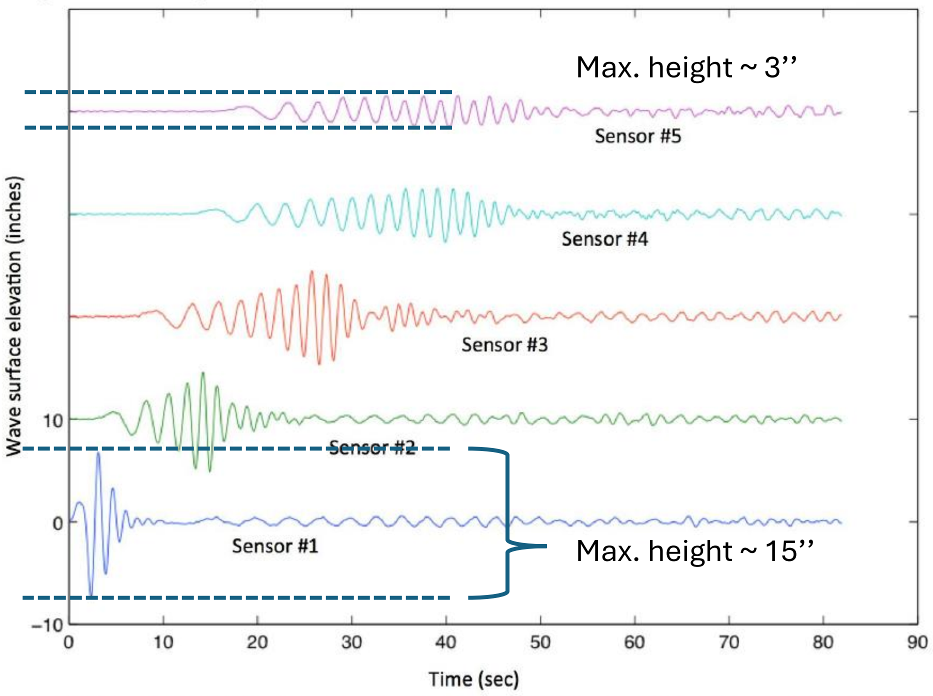


Figure 10. Shallow-water Run #6 - Cruising, 25 mph, 10’ standoff.

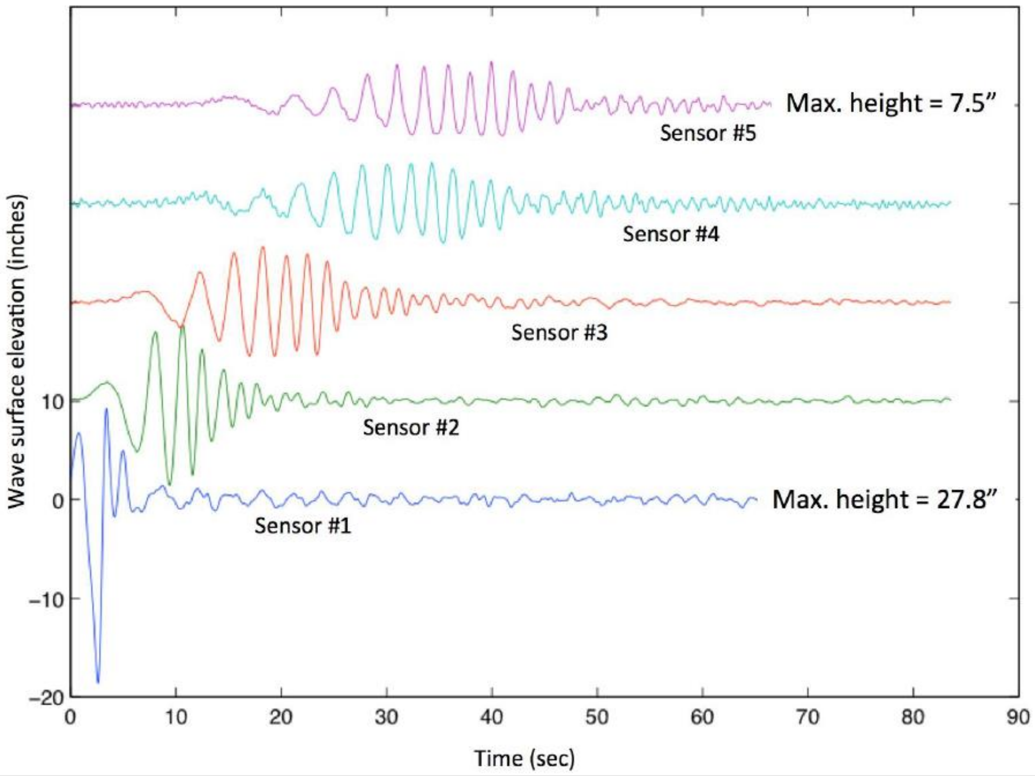
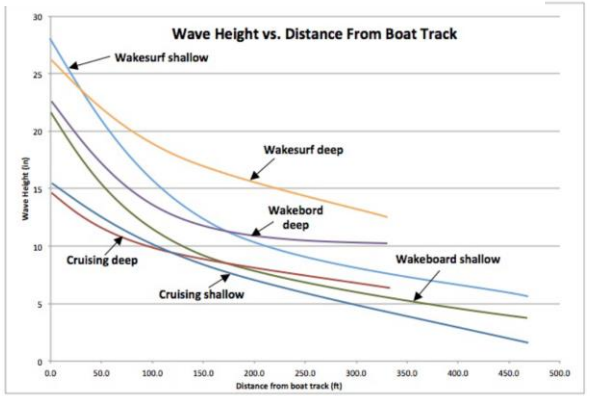


Figure 12. Shallow-water Run #24 - Wakesurfing to port, 11 mph, 10’ standoff.

- Max wave height of wakesurfing is 27.8” compared to 15” for cruising
- Chart at right is a smoothing of the data

Extrapolation Plot Of Max Wave Heights



Wave Height vs Distance from Shore

- The plot to the right illustrates the following:
    - Wave height of the wakesurf mode compared to cruising mode is nearly 2 times at 100 feet (deep water)
        - Cruise = 7.5”; wakesurf = 14.7”
    - Chart does not show how far away the wakesurf boat has to be to have the same wave height as the cruise mode at 100 ft (deep water tests), but linear extrapolation appears to indicate another 320’ would be required (Addendum slide 47)
    - U of M study graph indicated ~325’ additional distance
    - For the shallow water test, an additional ~220’ is required (Addendum slide 48)
- **But remember, these tests do NOT compare wake-sport boat to a recreational boat!!!**

Wave height conclusions of this study: wakesurf mode requires a lot more distance to dissipate compared to that of a recreational boat (remember, this study uses only one boat in different modes). ***See text box in upper right.***

For example: The weight of this boat is 5,900 lbs (65 gal gas, one driver) vs 3,797 lbs (dry) for a Bayliner 22’7” VA6 of nearly the same beam (102” wake-sport beam vs 96” beam on the Bayliner). Sun Tracker PARTY BARGE® 20 DLX weight = 2,080 lbs (dry) or 3,745 lbs (loaded)

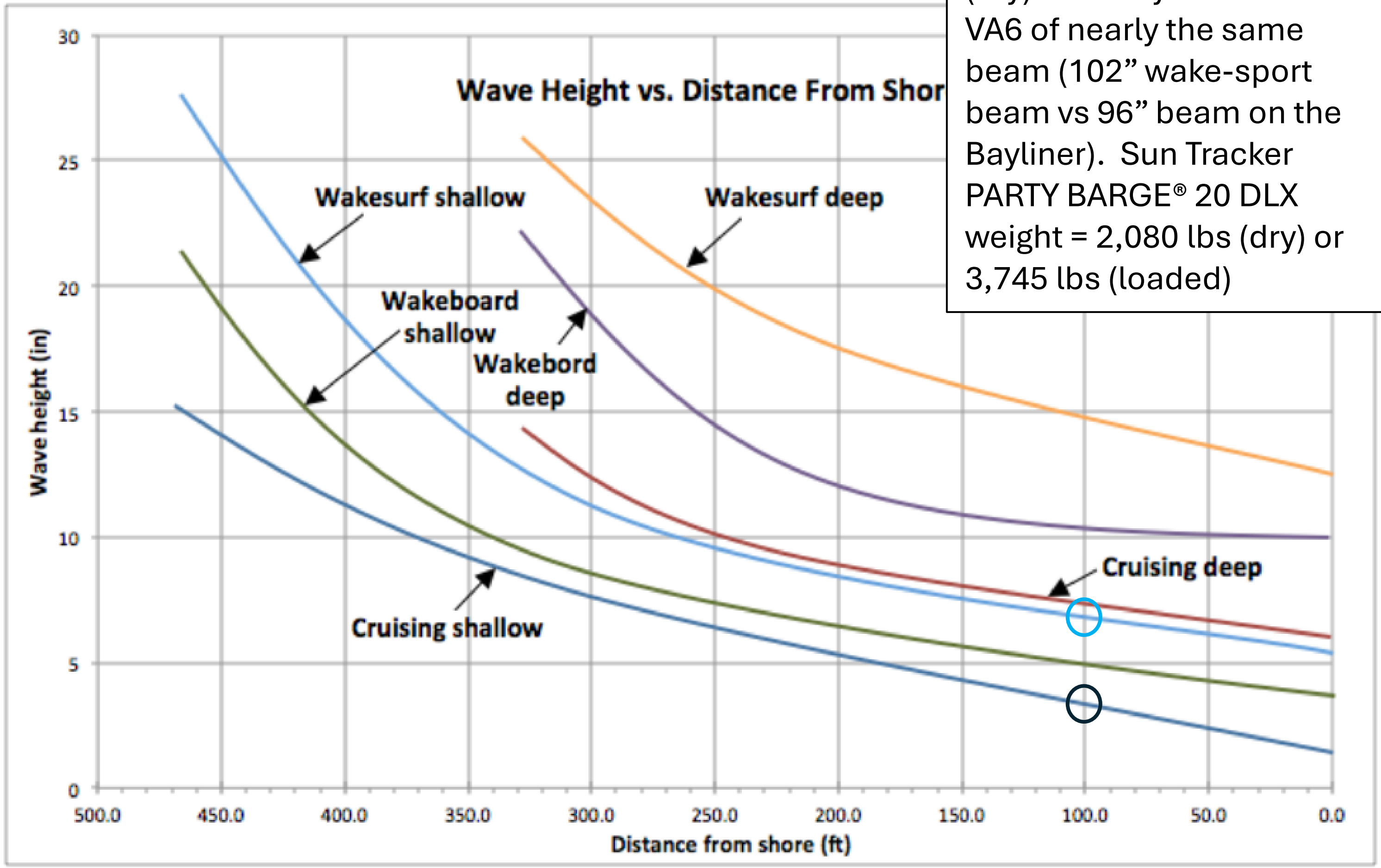


Figure 26. Wave height vs. distance from shore, trend lines only.

Converting Measured Data

Wave Height -> Power -> Energy

Symbolically illustrated as: $H^2(t)$ -> $P(t)$ -> E

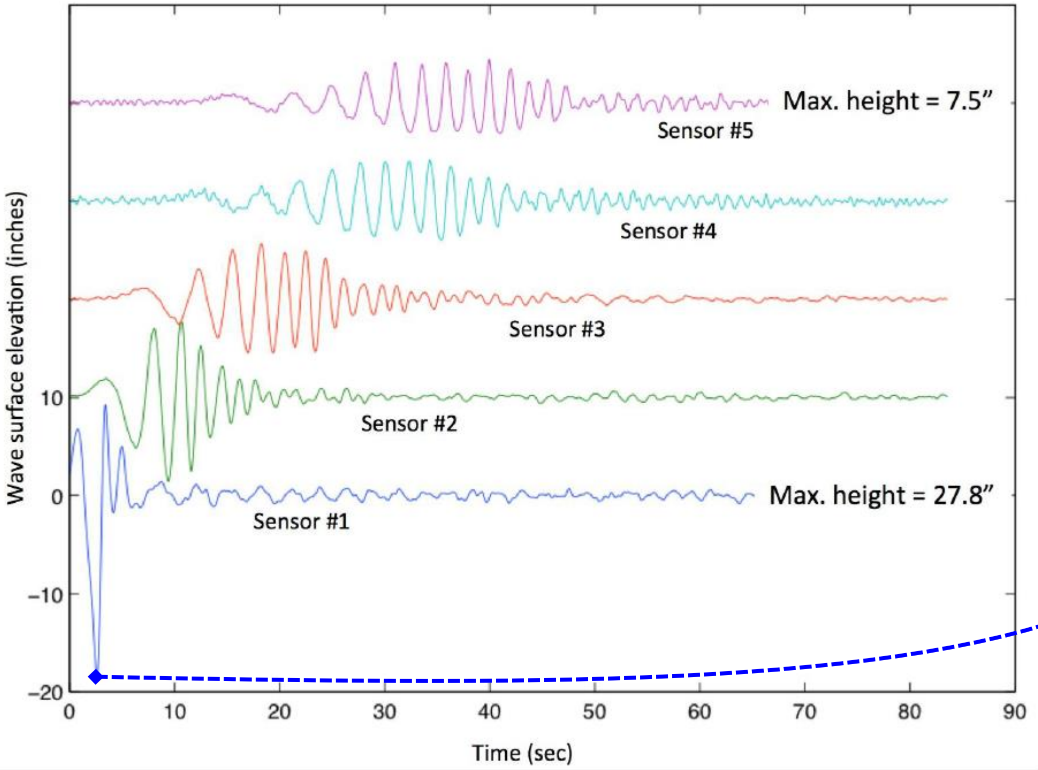


Figure 12. Shallow-water Run #24 - Wakesurfing to port, 11 mph, 10’ standoff.

Does the power curve make sense?

Power is proportional to wave height squared.

For largest waves:

S1 H^2 = 773

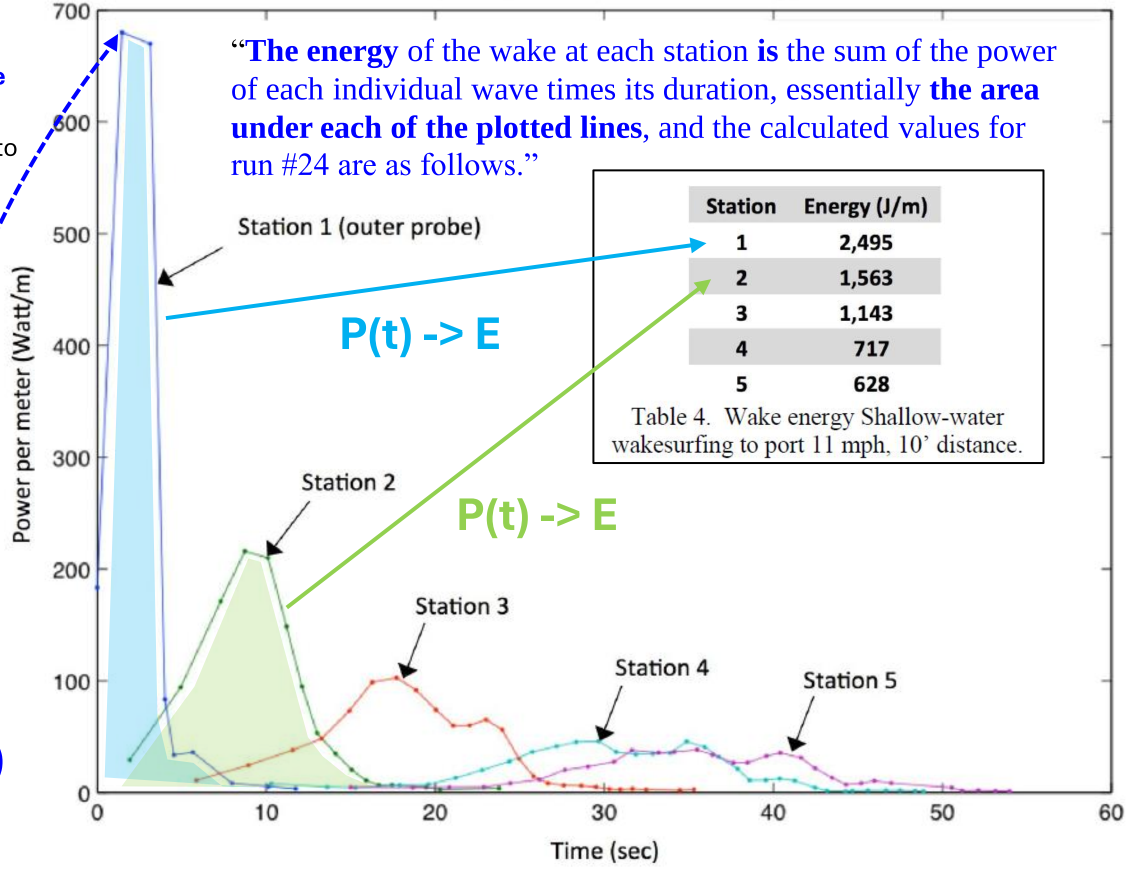
S2 H^2 = ~ 225

...

S5 H^2 = 56

$H^2(t)$ -> $P(t)$

See the addendum for an additional energy chart



Station	Energy (J/m)
1	2,495
2	1,563
3	1,143
4	717
5	628

Table 4. Wake energy Shallow-water wakesurfing to port 11 mph, 10’ distance.

Figure 22. Shallow-water Run #24 - Wakesurfing to port, 11 mph, 10’ standoff.

Note that all waves essentially dissipates within 60 sec after passing the sensor (the remaining wave height is 0). The wave has continued toward the shore

The figure above illustrates the wave power over time. The total area under each power curve is proportional to the total energy in the wave. The power curves for stations 1 (blue) and 2 (green) illustrate this concept

Slide 44 illustrates more details of the math in the wave height to energy conversion from a different reference, which is the same math used in the WISA report

Total Wake Energy

(Shallow, wakesurf mode)

- Do the energy plots make sense?
- Compare the power curve to the energy:
  - Energy is the area under the power curve
  - Area under Station 1 (shallow) ~ = 675 W/m x 3.5 sec = 2363 J/m
  - Energy shallow at sensor 1 = ~ 2480 J/m
- The total wake energy is reduced the further away the track is from the sensor (same as the wave height)
  - Station 2 (shallow) power integration = ~ (225 W/m) x (7 sec) = 1575 J/m, which matches Fig 23

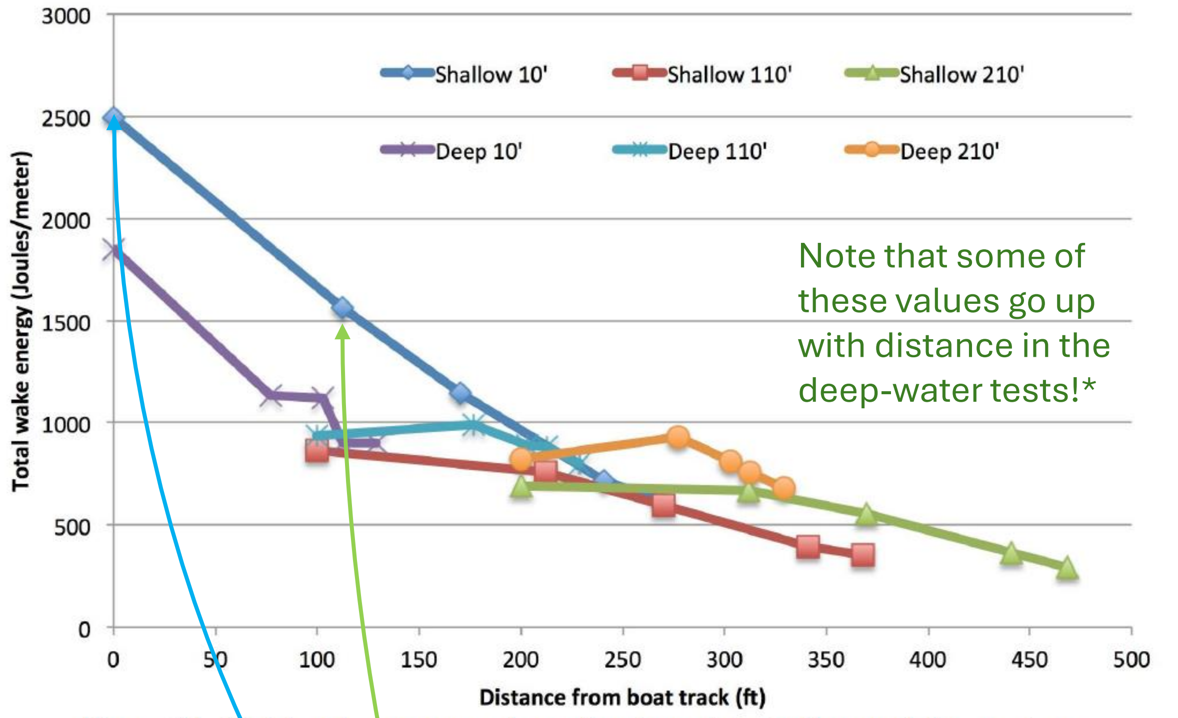


Figure 23. Total wake energy wakesurfing to port in shallow and deep waters.

Note that some of these values go up with distance in the deep-water tests!*

P(t) -> E

Integrate (sum) power over time = energy. Blue box is an approximation of the area for Station 1. Green box is for Station 2

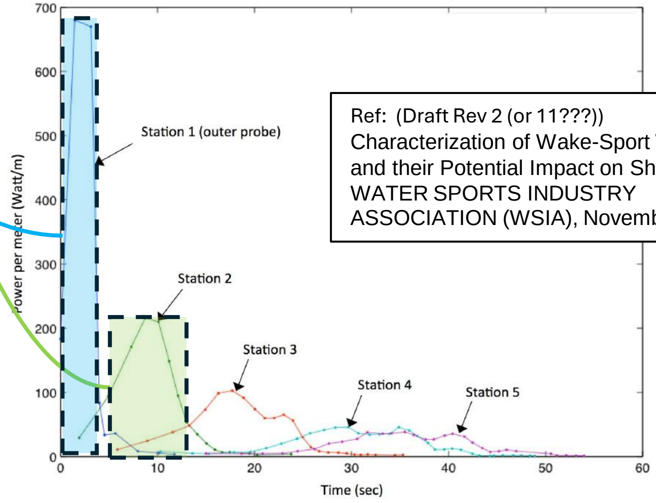


Figure 22. Shallow-water Run #24 - Wakesurfing to port, 11 mph, 10' standoff.

Ref: (Draft Rev 2 (or 11???)) Characterization of Wake-Sport Wakes and their Potential Impact on Shorelines, WATER SPORTS INDUSTRY ASSOCIATION (WSIA), November 2015

* The report does not illustrate any wave height plots over time in deep water. But Figures 18 and 19 of max wave heights show higher max wave heights at further distances (cruising at 25 mph and wakeboarding at 25 mph). See addendum

Cruising Mode Wave Energy Curves – *Selecting an Example for Later Use*

- The height to power to energy conversions were done to create plots of energy vs distance from the boat track for all measurements
- Plot to the right shows total energy for the deep-water sensor test area with the 3 boat tracks (10’, 110’, and 210’ from sensor #1)
- Track 2 (Deep 110’) at sensor 1 produces 349 J/m of energy. This example is used later to compare to the wind-wave energies (Table 7)

Note: This plot seems to illustrate energy increasing as the wave travels further. See addendum slide 45 for a different story. It is noted in the addendum that the deep water wave height data has more variance from the wave height trend lines than shallow water data.

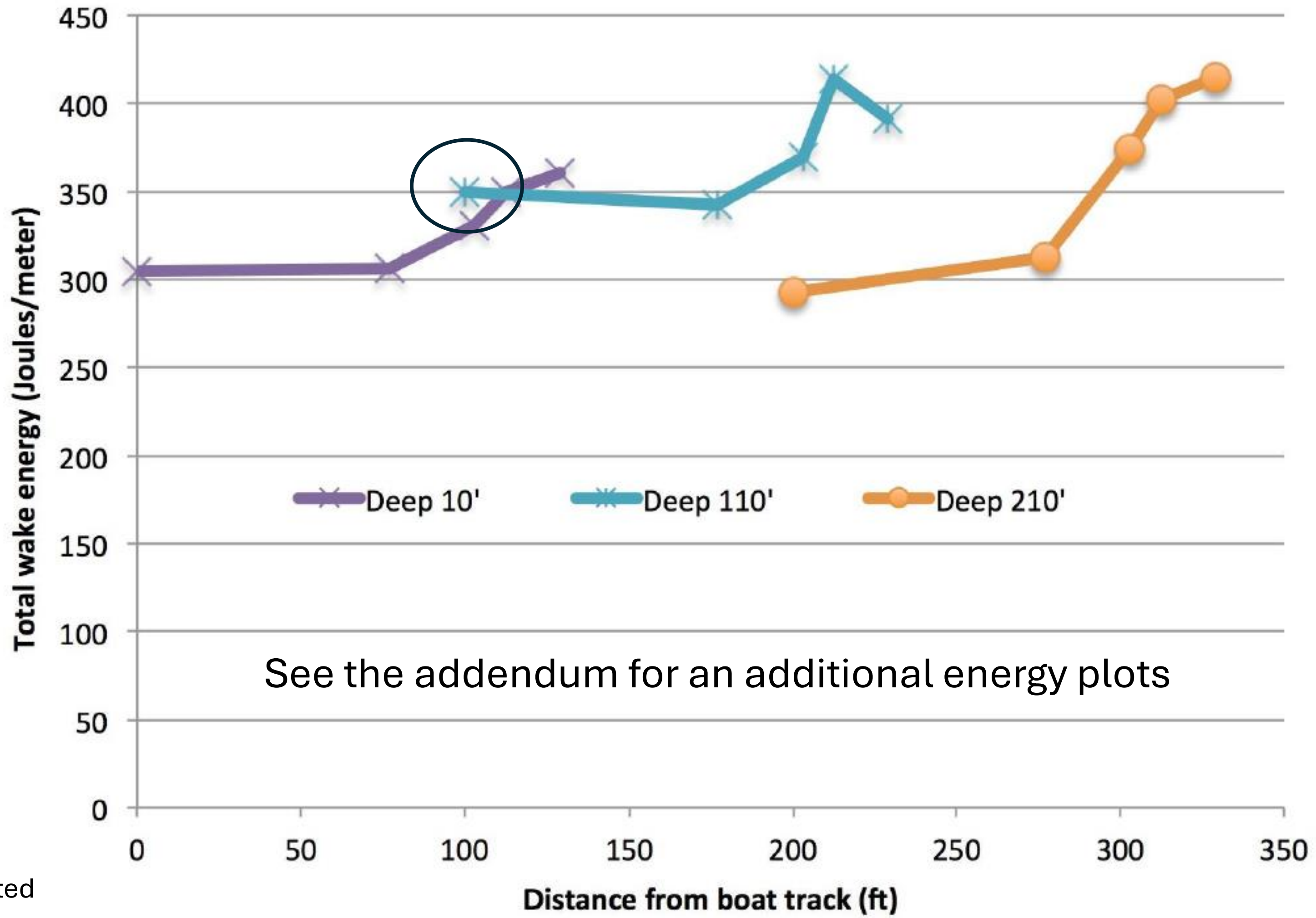


Figure 24. Total wake energy cruising at 25 mph in deep waters.

Wind Wave Height

- The study uses well recognized steady state mathematical models for wind-created waves to determine the energy received at shore by wind-generated waves
  - Fetch is the "… area of ocean or lake surface over which the wind blows in an essentially constant direction, thus generating waves"
  - Waves grow in height with more wind and longer distances (up to 1,000 miles)
  - https://www.britannica.com/science/fetch
- Wave height for a 20 mph wind with a 4-mile fetch: (see ● on the graph)
  - Requires ~ 1.5 hours of wind to reach steady state (mathematically predictable)
  - Produces waves of 1.19 ft in height (Table 5*)
- Wave height for 10 mph wind over 1 mile fetch is 0.3 ft (Table 6*) : (see ● on the graph)

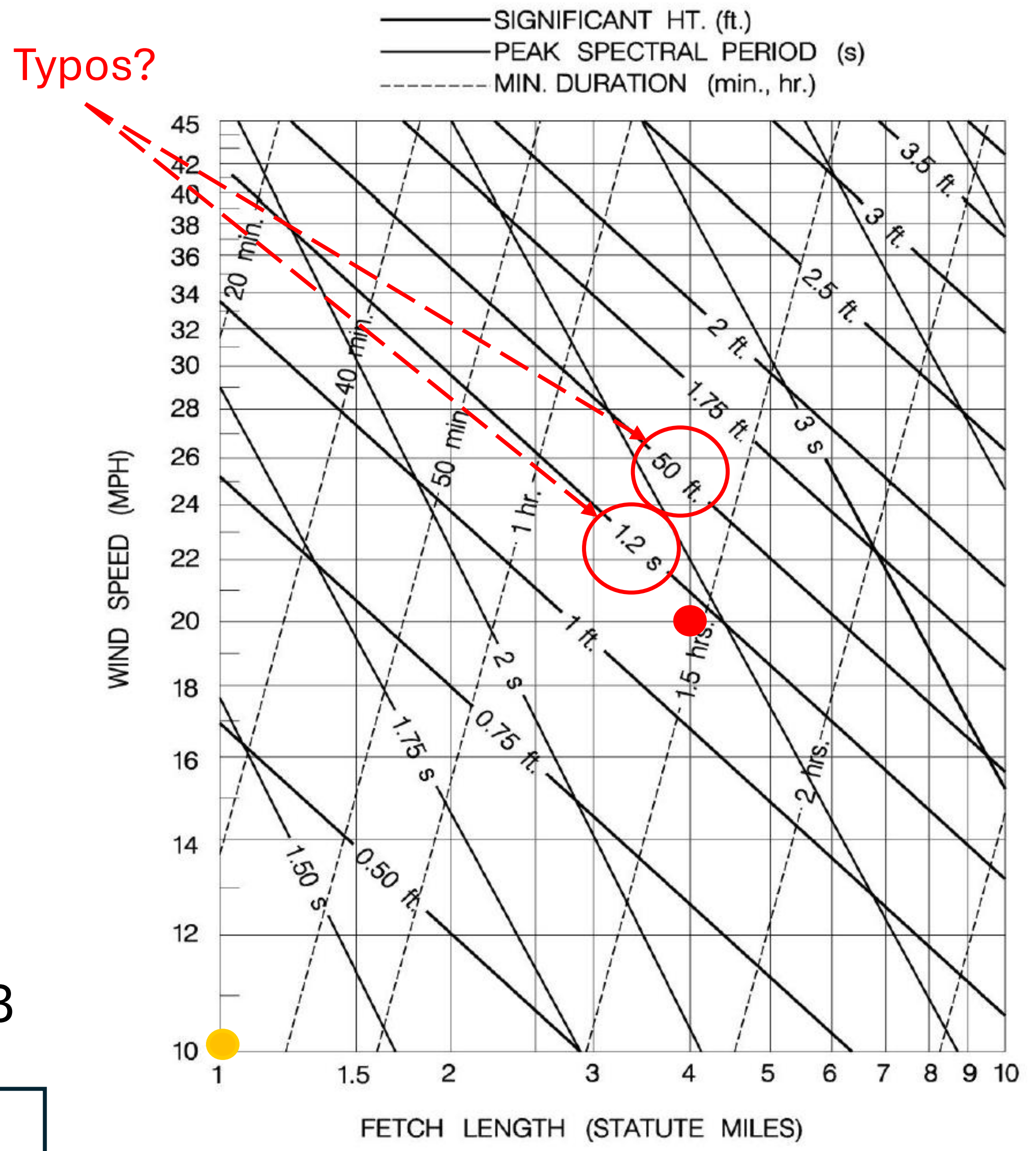
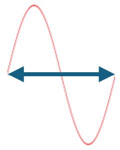


Figure 28. A nomograph for wind-driven waves (*VDOT Drainage Manual*).



Peak Spectral Period is the duration of the most energetic of the waves

* Tables 5 and 6 are on the next slide

Energy from Wind Waves

- Using the prior table and mathematical wave modeling, they determine the energy produced from 3 wind speeds and 2 fetches (distances)
  - Calculations assume the wind blows long enough to create steady state waves
  - The wind energy calculations follows the same process as for the wake-sport boat

Fig 28 data -> Table 5 -> modeling SW -> wind wave height over time ⟶ $H^2(t)$ -> P(t) -> E

Waves as a Function of Wind and Fetch

- Hmo = significant wave height
- Te = dominant wave period

Wind (mph)	Fetch			
	1 mile		4 miles	
	Hmo (ft)	Te (s)	Hmo (ft)	Te (s)
10	0.30	1.30	0.60	1.98
20	0.62	1.58	1.19	2.42
30	0.90	1.76	1.82	2.77

Table 5. Wave conditions vs. wind and fetch.

Wind Wave Shape Model

- Uses parameters of table to the left

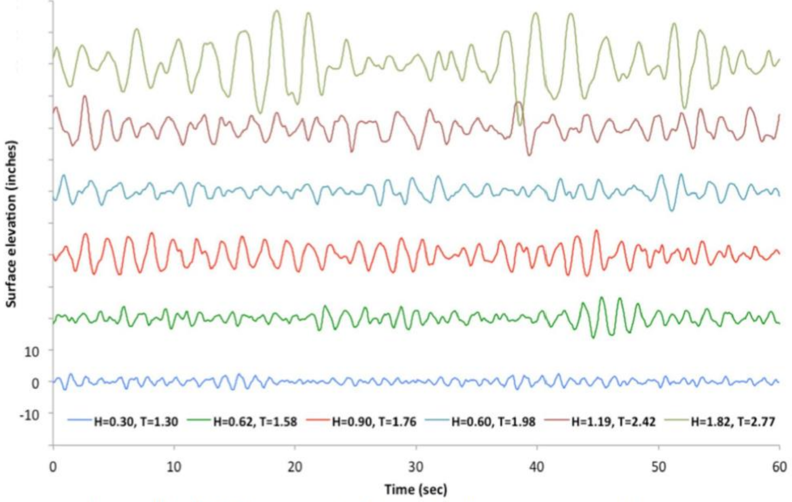


Figure 29. WAFO sea spectra time series for six wave specifications.

Calculated Wind Wave Energy

- Height -> Power -> Energy

Wind speed (mph)	Fetch (mi)	H_{mo} (ft)	T_e (s)	Energy (Joules/min)
10	1	0.3	1.3	208
20	1	0.62	1.6	790
30	1	0.9	1.8	3,148
10	4	0.6	2	1,046
20	4	1.19	2.4	2,418
30	4	1.82	2.8	17,572

Table 6. Energy of the Table 5 sea states in Joules/minute/meter.

Example highlighted on next slide

Calculated Wind Wave vs Boat Wave Energy

- Table illustrates the periodicity required of boats passing by the shore to equal the same energy of persistent wind waves
- Wind wave energy is calculated over 60 seconds with a one-meter width
- The periodicity of the boat is determined by finding the amount of time the boat waves will produce the same energy as the wind
- For a boat cruising by the shore at 110’
  - Wind: 208 J/m is to 60 seconds as
  - Boat: 349 J/m is to X seconds
  - X = (349*60)/208 = 101 seconds

$$\frac{208}{60\ s} = \frac{349}{X\ s}$$

Wind vs Boat

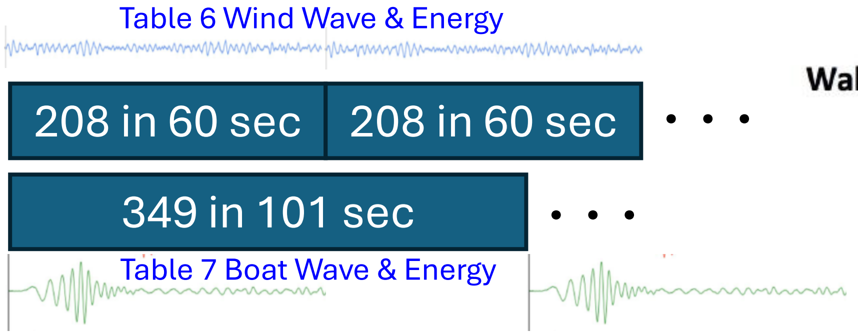


Table 6 Wind Sample vs Table 7 Boat Sample

Wind speed (mph)	Fetch (mi)	H_{mo} (ft)	T_e (s)	Energy (Joules/min)
10	1	0.3	1.3	208

Operating mode	Water depth	Stand off (ft)	Total wake energy (J/m)	Recurrence equivalent (sec) 10 mph/1mi	Recurrence equivalent (sec) 20 mph/4 mi
Cruising	deep	10	305	88	8
		110	349	101	9
		210	293	85	7
	shallow	10	280	81	7
		110	274	79	7
		210	230	66	6
Wakeboarding	deep	10	850	245	21
		110	616	178	15
		210	602	174	15
	shallow	10	666	192	17
		110	519	150	13
		210	478	138	12
Wakesurfing	deep	10	1846	533	46
		110	937	270	23
		210	821	237	20
	shallow	10	2495	720	62
		110	868	250	22
		210	692	200	17

Table 7. Total wake energy and wind-wave recurrence equivalent.

Assessment of Study's Conclusions (Boat vs Wind)

- "By comparing boat-wave energy with the energy of wind waves associated with various combinations of wind speed and fetch distance, equivalent recurrence intervals can be determined, 1-mile the frequency of wake events that would equal a specified wind condition. **Because wind waves are persistent, in many settings they represent a more significant source of shoreline impact than boat wakes**."
- The phrase "in many settings" is somewhat misleading. **The likelihood that the real-world characteristics are the same as the wind model assumptions is overstated**, i.e., this is a general statement that leaves the reader pondering the applicability of the statement
    - The nature of the wind wave models they use requires persistent wind and long fetches. The plot shown on slide 25 (Fig 28 nomograph) does not have wind speeds below 10 mph. The shortest wind persistence shown is approx. 47 minutes at 10 mph with a 1-mile fetch
    - Real world characteristics of the lake shape, tree line, prevailing wind direction(s), strength, and duration, etc., are not addressed. For example, how strong are prevailing (persistent) winds, how do they align with the shoreline, are they in the same location on the lake as boating, etc.
- The authors discuss the **reduction of a wave's height in terms of percentage drop over distance** as they leave the boat; they do not point out the fact that **percentage drop is not as important as the remaining height (e.g., wake-sport vs recreational boating) at the destination (dock or shoreline)**
    - The data (graphs, etc.) presented surely indicate that wakeboard or wakesurf modes of wake-sport boats produce larger waves, even after wave dissipation as compared to recreational boats at a given distance (shoreline, dock, another watercraft, etc.)
    - Remember, this study used the same wake-sport boat, but without additional ballast, as representative of recreational boats. A normal recreational boat of similar beam width and length likely has less displacement than wake-sport boats (dry weight comparison)
    - Yes, there is a trade between weight and beam width as it applies to displacement, but I don't have any data on it
- Another **element of the study not addressed is breaking or tensile strength of objects receiving the wave energy**. **The unstated assumption that receiving lower energy over time is the same as receiving strong energy repeatedly does not apply to breakage**
    - Consider for example stretching a rubber band 1000 times, but never to the point of breaking vs one stretch that breaks the rubber band –the total energy imparted by each experiment could be equal

Application of the Analysis and Conclusions for Sacheen Lake

Sacheen Lake Wind

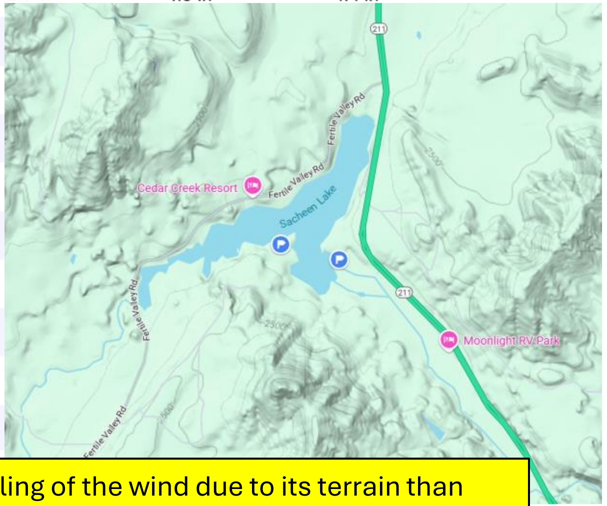
Ref: https://www.weatherworld.com/climate-averages/wa/sacheen+lake.html

Sacheen Lake Monthly Climate Averages

12 Month Climate Scroll °F °C

Month	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperatures	Hi 31°F Lo 20°F	Hi 34°F Lo 21°F	Hi 43°F Lo 27°F	Hi 52°F Lo 33°F	Hi 64°F Lo 42°F	Hi 71°F Lo 48°F	Hi 83°F Lo 56°F	Hi 83°F Lo 56°F	Hi 72°F Lo 48°F	Hi 54°F Lo 37°F	Hi 39°F Lo 28°F	Hi 31°F Lo 21°F
Avg. Wind Speed	3 mph	4 mph	4 mph	5 mph	4 mph	4 mph	4 mph	4 mph	4 mph	4 mph	4 mph	3 mph
Avg. Precipitation	3.3 in	2.4 in	3.4 in	2.6 in	2.5 in	2.2 in	0.5 in	0.7 in	1.3 in	2.8 in	4.3 in	4.4 in
Average Humidity	94%	91%	86%	74%	67%	64%						
Avg. Cloud Cover	71%	67%	59%	49%	39%	33%						
Pressure Average	30.2 in	30.1 in	30.0 in	30.0 in	29.9 in	29.9						
Average Dry Days	10	11	13	19	24	24						
Avg. Precip. Days	12	10	11	9	7	6						
Avg. Snow Days	10	7	7	2	0	0						
Average Fog Days	1	1	1	0	0	0						
Average UV Index	1	1	2	2	4	5						
Avg. Hours of Sun	78	73	104	135	195	220						

Averages are based on historical weather data from the past 10 years. Click and drag this table...

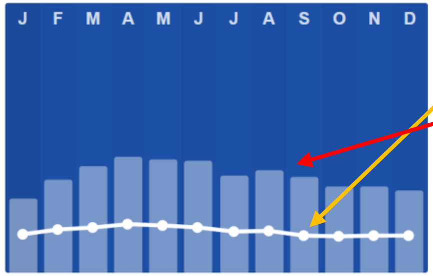


Deer Lake is likely to have more tunneling of the wind due to its terrain than Sacheen Lake, i.e., higher wind speeds. The same scale is used on both maps.

- Sacheen Lake's wind averages are 5 mph or less
- Yes, Sacheen Lake receives much higher winds
- A wind speed occurrence curve (probability distribution) was not available for direct use. A specific reference's general modeling of the statistics is used.
- Closest available data aiding in statistical understanding of wind was for Deer Park airport; the average and average maximum winds are used

Climate (2010–Present)

Deer Park, Deer Park Airport (13 miles)



Deer Lake Winds (> Sacheen)

- Ave Range: 5.5 to 6.7 mph
- Ave Max Range: 11.3 to 17.4 mph
- Ave Max is 2 to 2.5 x Ave

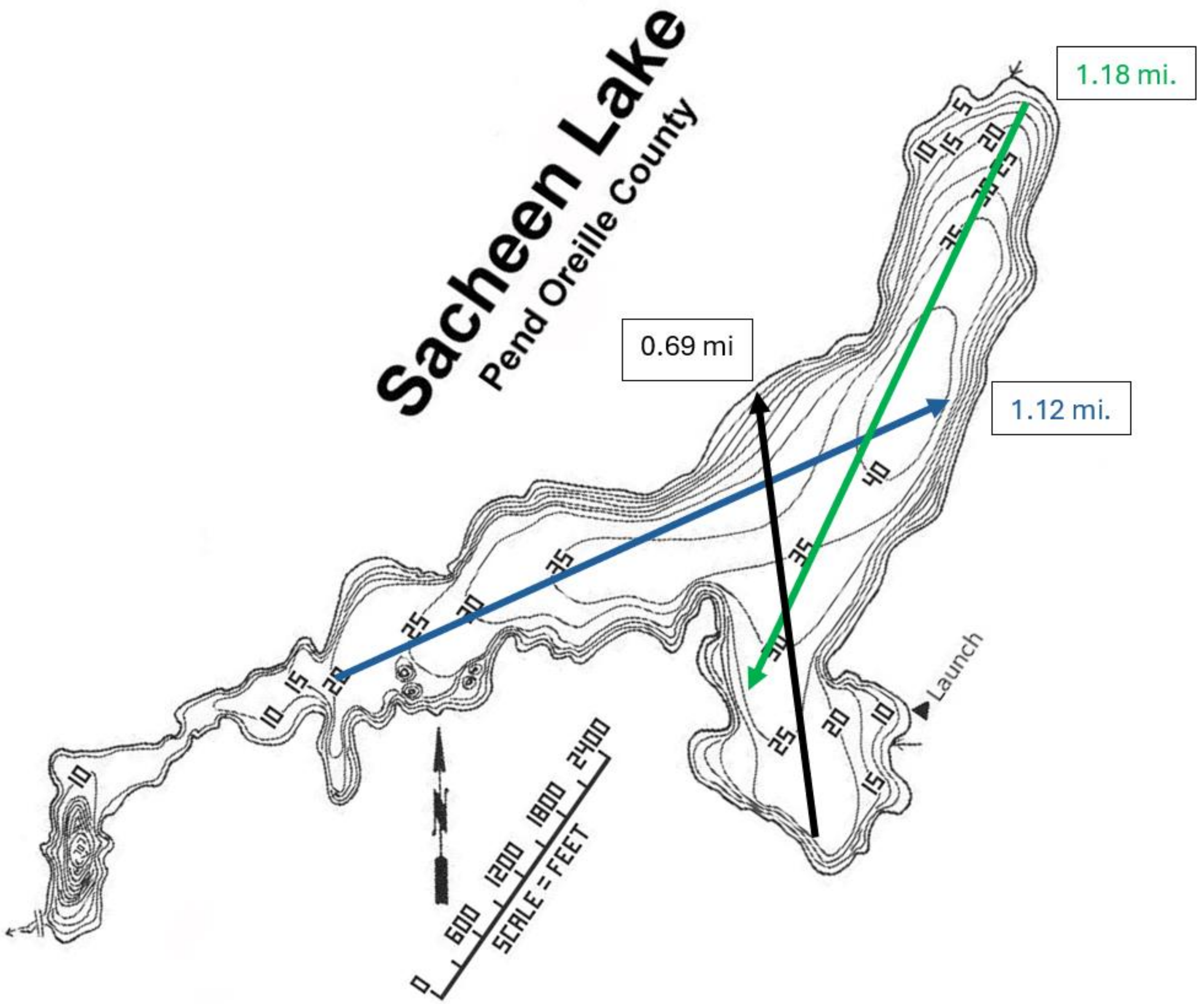
Ref: https://wind.willyweather.com/wa/pend-oreille-county/sacheen-lake.html

Sacheen Lake Prevailing Wind and Fetch

- Prevailing Winds (based on experience) and Fetch Distance (Google Maps measure function)

Direction	Fetch
SW to NE	1.12 miles
NNE to SSW	1.18 mi.
SSE to NNW	0.69 mi.

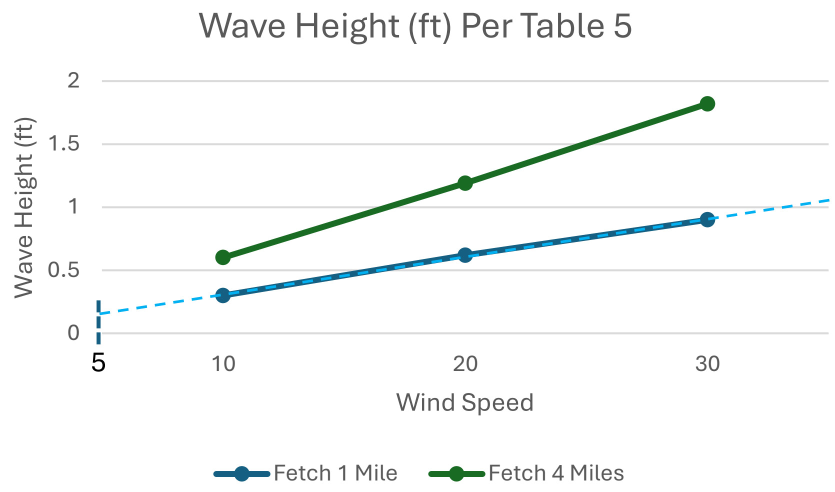
- The study did not have data on steady state winds below 10 mph
  - However, those waves were only 0.3’ (3.6”) high with 10 mph winds on a 1-mile fetch
- Sacheen’s wave heights on average wind days will be less than 3.6” (more on this later)
- Note: The prevailing winds impart their full fetch distance energy on only a limited range of the shoreline! A majority of shoreline around Sacheen Lake has a fetch much shorter than 1 mile



Note that the assumed prevailing wind directions match the longest fetch where the lake speed is 35 mph. This is the “best” combination to obtain the largest wind waves.

Wave Height for 5 Mph Winds (Extrapolation) & Resultant Wind Energy

- Linear extrapolation of Table 5 data implies a wave height of ~ 1/3 * 0.5' = 0.15' (=1.8"). See graph to the right
  - The lines to the left are already linear in nature, so linear extrapolation should be "accurate"
- This height for 5 mph is ½ of the height of the 10 mph wind waves which produces an energy of 208 J/m
- Therefore, the energy (proportional to H squared) should be ¼ of the energy or 52 J/m for 5 mph over a 1-mile fetch
- Wakesurfing in the study at 110' from sensor 1 in deep water produced 937 J/m
  - In order to produce the same energy as the 5 mph, the wakesurf mode boat 110' from shore needs to meet the following: 937/X = 52/60. X = 937*60/52 = 1,081.2 seconds
  - Repetition rate of wakesurfing every 1,081 seconds (18 minutes) produces the same total energy as Sacheen's prevailing average wind at 5 mph for a 1-mile fetch of prolonged wind (from Figure 28, at least 50 min of prevailing wind is required for steady state waves)
- The probability of average max winds of 10 mph is low as illustrated in the addendum slide 49
  - Recall that Deer Valley data showed 2 X ave wind = ave max wind
  - High winds should, conceptionally, have a small probability of occurrence



Wind (mph)	Fetch 1 mile Hmo (ft)	Fetch 1 mile Te (s)	Fetch 4 miles Hmo (ft)	Fetch 4 miles Te (s)
10	0.30	1.30	0.60	1.98
20	0.62	1.58	1.19	2.42
30	0.90	1.76	1.82	2.77

Table 5. Wave conditions vs. wind and fetch.

Source data for above graph

		...off	Total wake energy (J/m)	Recurrence equivalent (sec) 10 mph/1mi	Recurrence equivalent (sec) 20 mph/4 mi
			305	88	8
			349	101	9
			293	85	7
			280	81	7
			274	79	7
			230	66	6
			850	245	21
		110	616	178	15
		210	602	174	15
		10	666	192	17
	shallow	110	519	150	13
		210	478	138	12
Wakesurfing		10	1846	533	46
	deep	110	937	270	23
		210	821	237	20
		10	2495	720	62
	shallow	110	868	250	22
		210	692	200	17

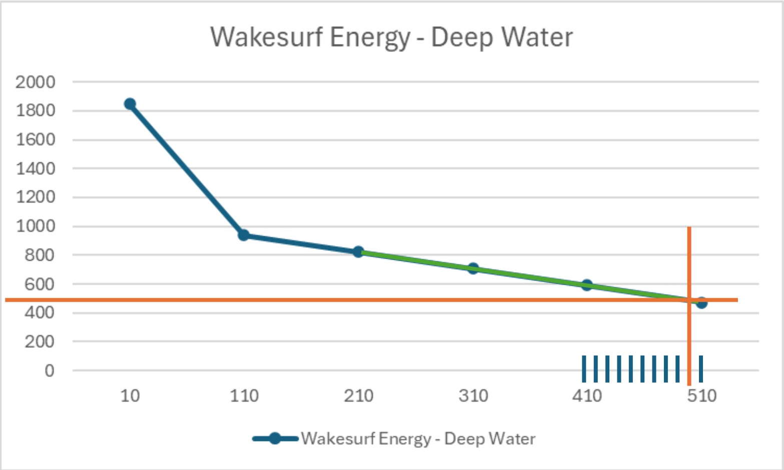
Table 7. Total wake energy and wind-wave recurrence equivalent.

$H^2(t)$ -> P(t) -> E Source data for energy calculation

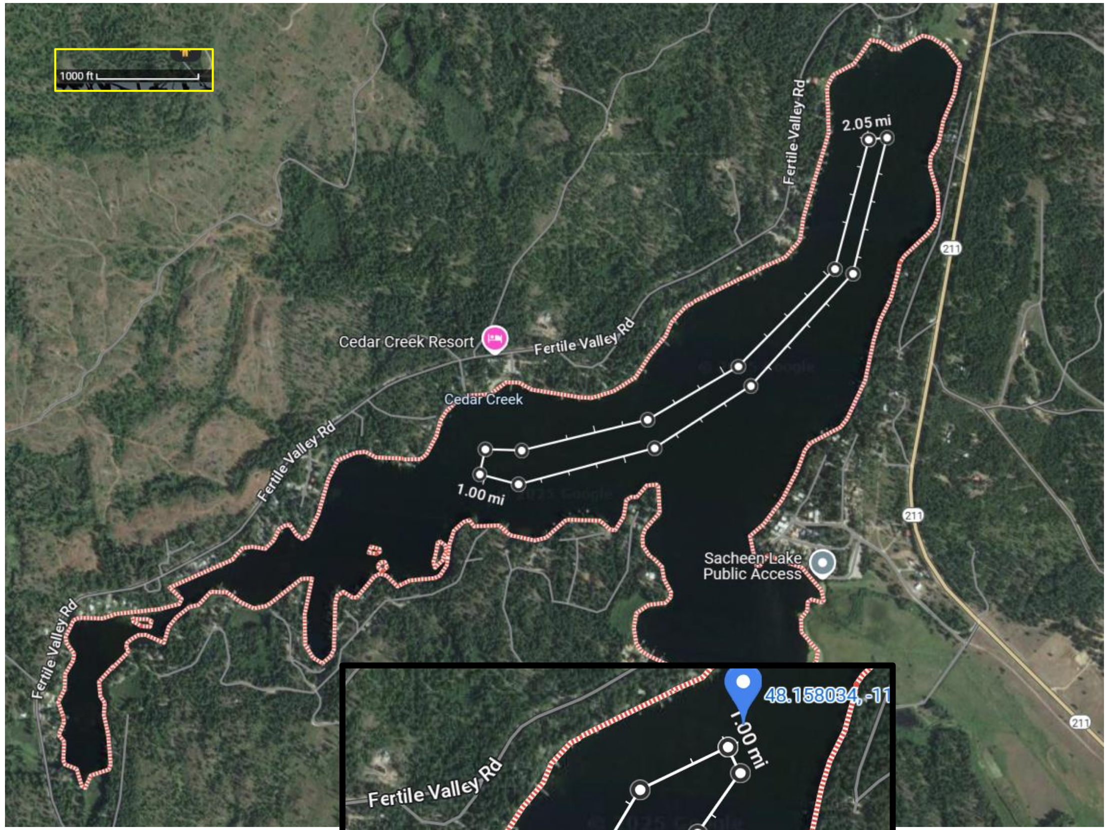
One Surf Loop Around Sacheen – Energy Produced

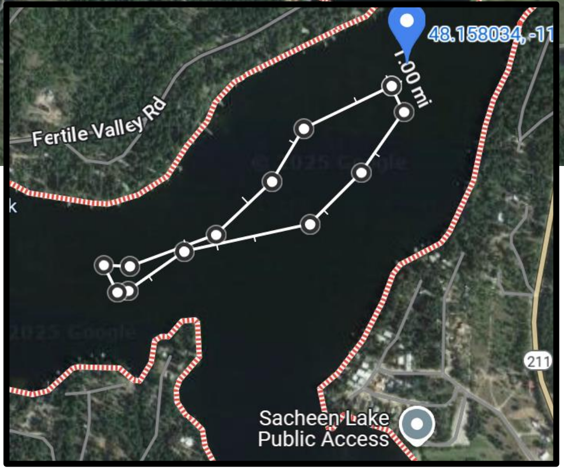
- Long loop distance* on larger map to the right is 2.05 mi. Loop path is always > 100' from shore
- Time for the loop = Distance of the loop/Rate of travel
  - Tsurf = 2.05mi/10 mph = 12.3 min
  - Twakeboard = 2.05/20 = 6.15 min
  - Tcruise = 2.05/30 = 4.1 min

  Assuming no other lake traffic or falls
- If the loop is made smaller and kept ~ 500ft from shore:
  - Tsurf = 1mi/10 mph = 6 min
  - See "Smaller surfing loop" map to the lower right
- Energy of wakesurf at shore on a loop 500 ft from shore = 485 J/m
  - See below chart. Green line is the linear extrapolation, orange lines show energy at 500 ft



Wakesurf Energy - Deep Water		
Distance from Sensor	Energy (J/m)	Source
10	1846	Table 7
110	937	Table 7
210	821	Table 7
310	705	Extrap
410	589	Extrap
510	473	Extrap
500	**484.6**	**Calc**



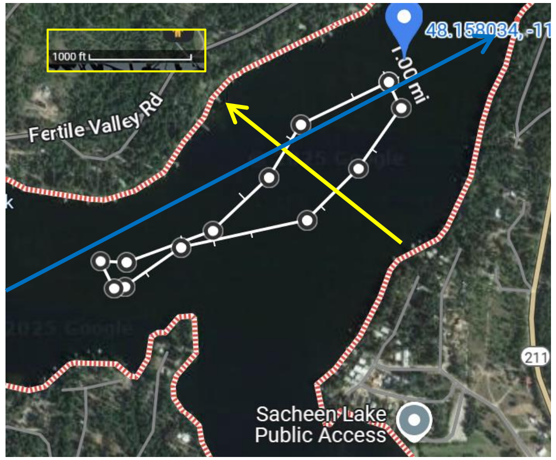


Smaller surfing loop

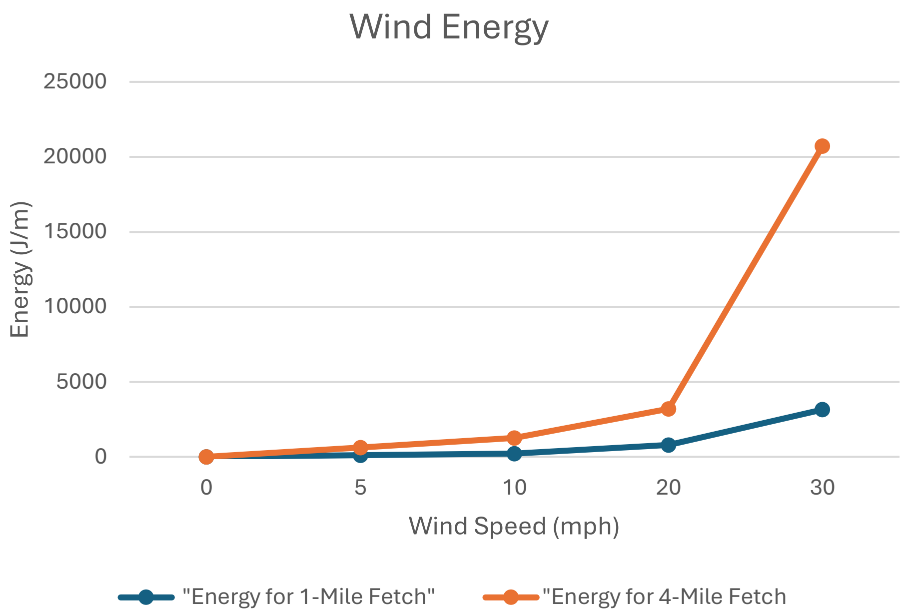
* Distances determined by Google Maps

Wind Comparison to One Short Loop Around Sacheen

- Energy at shore with 5 mph winds and 1-mile fetch = 104 J/m (below chart/graph). How often can the boat in wakesurf mode go by and produce the equivalent shoreline energy?
  - Solve: 104/60 = 485/X -> X = 4.7 min
  - The wakesurf boat would have to go by every 4.7 minutes to produce the same total energy the wind at 5 mph. This is more frequent than going around a 1-mile loop at 10 mph (once every 6 min.)
- The fetch length of the winds perpendicular to the wakesurf loop and hitting against the shoreline is about 1750 ft (e.g., width of the lake from NW to SE)
- Energy from the wind imparted on the shorelines opposite the boat path would be a lot less than the 104 J/m of a 5 mph prevailing wind over a majority of the ski path because there is insufficient distance to build up the waves to the equivalent height obtained in a 1-mile fetch
- The boat's energy (485 J/m or 5X of the prevailing wind) will reach most of the shoreline around the entire boat path. The periodic, much higher energy from the boat (vs the wind) will have a greater impact when considering breaking forces



Wind Direction Key
Perpendicular to Path
Prevailing (1.12 mi)



$H^2(t)$ -> P(t) -> E

Wind Speed	Fetch	Energy (J/m)	Source
0	1	0	Extrap
5	1	104	Extrap
10	1	208	Table 6
20	1	790	Table 6
30	1	3148	Table 6

Note that on slide 32, the wind energy was calculated at 52 J/m. The number on the linear extrapolation is 2X what was previously calculated*. That is, the analysis on this slide assumes more wind energy than there might be.

* Depending on the parameters, a linear curve will be higher than an exponential curve in the beginning

Conclusions for Applicability to Sacheen

- Sacheen residents complain about broken items, waves too large to be in/around due to boating, reaction of docks to wake-sport boats (and 100' distance violators), and their inability to be on their docks or in small watercraft during wake-sport boating
- Sacheen's *prevailing average wind* waves do not produce significantly large waves (around 2" in height – trough to crest) nor do *prevailing winds* impart energy on all of the lake's shoreline
- An average wave height of prevailing winds over a 1+ mile of fetch on Sacheen lake will not have a significant amount of energy in it (~ 104 J/m)
- The average wave height from winds along the shoreline perpendicular to the path of the small-loop wakesurf path is produced with a fetch of about 1750 ft. Therefore, the energy produced will be a lot less (E << 104 J/m) than that of the nearly 1-mile fetches on Sacheen Lake previously illustrated herein
- Items on Sacheen Lake that break (docks, retaining walls, etc.) are likely to have a much higher breaking point in terms of energy required to break them as compared to the energy produced by prevailing average winds on Sacheen*
  - The analysis illustrated that wake-sport boats on Sacheen impart ~ 5 times the energy as prevailing winds
- Shoreline erosion can occur with smaller, persistent waves (prevailing winds or not), but larger waves are also more likely to pick up bottom sediment and use it as a breaking element against the shoreline*

---

* These comments are those of the author using logic.

Conclusions for Applicability to Sacheen (cont.)

- The executive summary of the study states: “In all but the most protected of shorelines, it would be difficult for boating to match the role of wind waves and natural currents on shaping shorelines.”
- Sacheen Lake’s real-world conditions are significantly different from the wind assumption in the study
  - Sacheen Lake’s average (statistically persistent) wind speeds are ½ of the smallest speed considered in the study
  - Sacheen has treelined protected boundaries around almost the entire lake
  - Sacheen fetches are short, especially along the shorelines perpendicular to boat traffic, and the winds perpendicular to those shorelines cannot build up waves over a sufficiently long distance
  - Sacheen Lake does not have significant shoreline natural currents due to waves*
    - There are however directional currents based on the flow of water from Moon Creek, for example
  - Shorelines may also be shaped by the waves picking up already broken off parts of granite rock and using the wave force to beat the rock pieces against the shoreline (I see it at my place with large waves, but not typically with wind waves)*
  - Sacheen Lake residents have visually experienced breaking forces which have NOT been attributed to wind

- Conclusion: Real-world considerations strongly suggest that Sacheen Lake’s shorelines, docks, etc., are not as affected by the winds as suggested in the study. In fact, the data shows that Sacheen’s wind effects are significantly less than those presented in the study as well as significantly less (5 time less) than wake-sport boats on Sacheen Lake at 500 ft from shore
- Breaking strength analysis was not done in the study, but evidence on our lake illustrates that it is a concern, and eyewitnesses indicate that wind has not been the cause of crumpled ramps, etc.

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* These comments are those of the author using logic.

Questions / Comments?

Wrap Up

- Thank you for attending and taking an interest in what goes on at Sacheen Lake!
- The presentation is posted on the SLA website
- The wave damage survey will soon be released via email and post cards (trying to reach all lake property owners)
  - The survey is digital and access requires the link we'll provide
- Please take the survey so we all have a better understanding of how our community feels about wave damage
- The wave damage survey results will be presented at the SLA's June 2025 Annual Meeting and posted on our website
  - We will likely host a Zoom call for this year's Annual Meeting as well as meeting at the Hwy 211 fire station

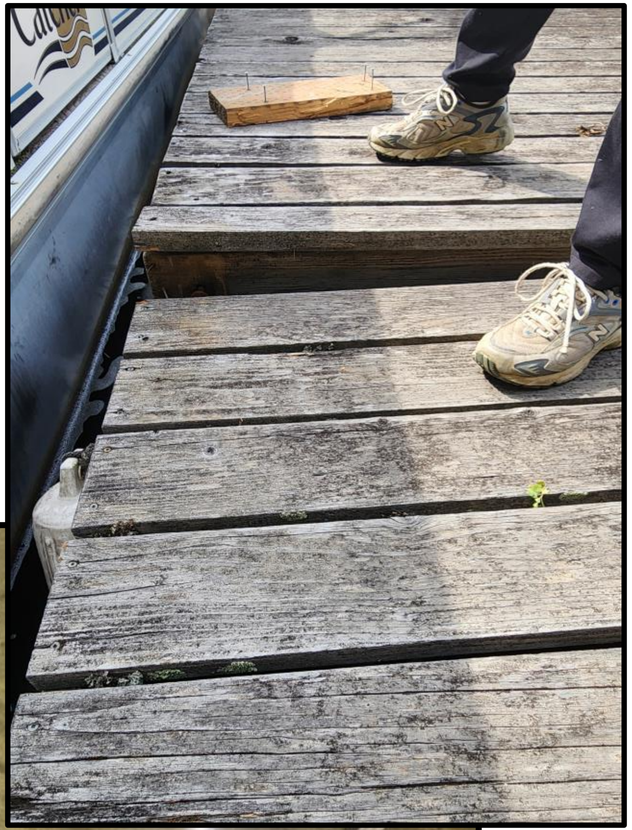
Addendum / Backup Slides

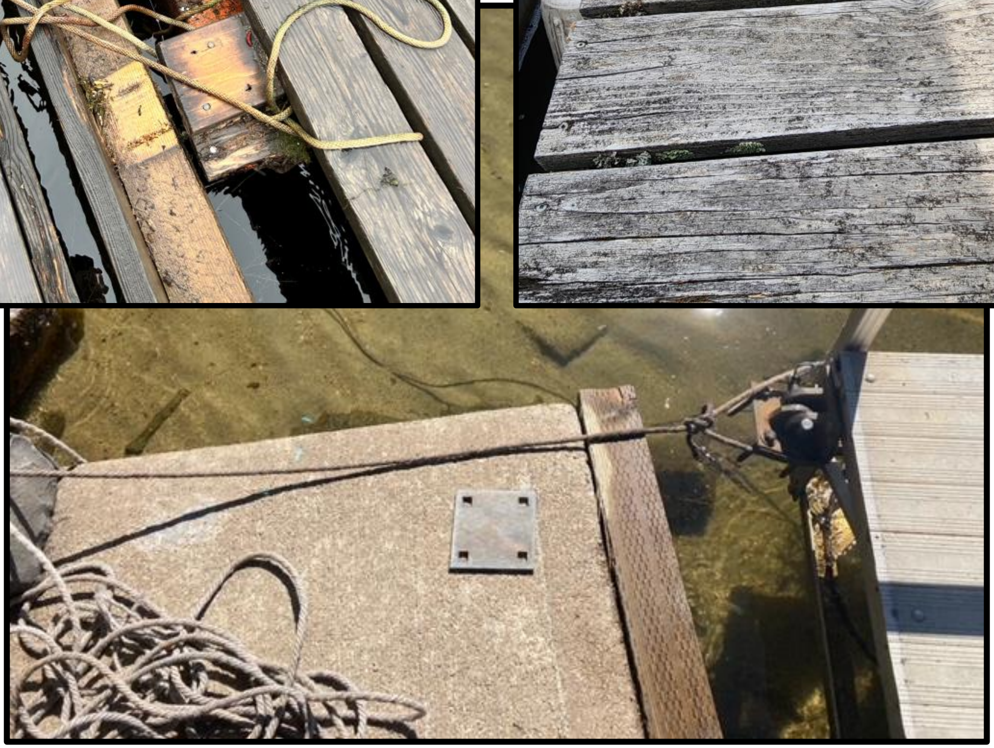
From SLA Oct 2024 Wave Damage Meeting Presentation

Shoreline Damage – Retaining wall, Dock landing, actual shoreline

Dock Damage

- Wave action has been pushing on docks and breaking anchor chains, moving docks, and breaking dock pieces apart.
- Damage: “We had to disconnect our floating dock sections and upgrade the hardware pinning them together. Cost was $1,012. We did this work ourselves, otherwise it would have been more.”
- Dock movement e.g.: I tied a corner of my dock to a tree so the ramp would not fall off the landing and get bent.





From SLA Oct 2024 Wave Damage Meeting Presentation

Dock Damage

July 2024 damage

From SLA Oct 2024 Wave Damage Meeting Presentation

Non-attributed Recent Email Quotes on Large Wakes

- 8/8/24: “What is done about the large waves that are created by the wake boats, and people not allowed to enjoy their own dock and the concern of children swimming when the waves come in. It is powerful enough to throw you against the dock or knock children down or off their floating devices, even when they are in the bigger part of the lake …”
- 8/12/24: Based on a photo of a crumpled ramp - “… their approach really took a beating. My approach broke a month ago and yesterday a ski boat was washed off its boat lift and ended up on a rocky beach”
- 8/26/24: “We live on Eastshore, directly across from what people say is the biggest part of the lake. The wake boats go back and forth, and back and forth, sometimes with a jet ski jumping the waves it's making. Pretty soon the waves breaking on our shoreline are huge. As a result, we can't let our toddler grandson play on our beach when the wake boats are out because the waves will knock him down. Besides it being dangerous, it's sadly made him afraid to play there. We completely disagree with those who have said that as long as they stay in the middle of the biggest part of the lake they won't affect the shoreline. Our lake is too small for wake boats. Period.”
- 9/3/24: “What a frustrating weekend at the lake due to HUGE waves created by the "Wake Setter" black surf boat and other surf boats. Our shoreline and dock were beat to hell with no reprieve all weekend. We had ropes snap and had to move our dock 10' over to the east to get it to the original position.”

How to Convert Wave Height to Power to Energy

- Reference: https://www.azocleantech.com/article.aspx?ArticleID=227

$H^2(t)$ -> $P(t)$ -> E

Wave Power Formula

In general, larger waves are more powerful but wave power is also determined by wave speed, wavelength, and water density. The power of a wave is determined by the 'Wave Power Formula'. In this case, the 'power 'does not refer to the power that would be produced by a wave power machine, rather it means the 'wave energy flux', or the transport rate of wave energy. In deep water where the water depth is larger than half the wavelength, the wave power is found using the following equation:

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T \approx \left(0.5 \frac{\mathrm{kW}}{\mathrm{m}^3 \cdot \mathrm{s}}\right) H_{m0}^2\ T,$$

Where P is the wave energy flux per unit of wave-crest length, Hm0 the significant wave height, T the wave period, ρ the water density and g the acceleration by gravity. The above formula also says that wave power is proportional to the wave period and to the square of the wave height. If the significant wave height is given in meters, and the wave period in seconds wave power has units of kilowatts (kW) per meter of wavefront length.

Wave Energy

In average ocean conditions, the average energy density per unit area of sea surface waves is proportional to the wave height squared, shown in the following equation:

$$E = \frac{1}{16} \rho g H_{m0}^2,$$

where E is the mean wave energy density per unit horizontal area (J/m2), the sum of kinetic and potential energy density per unit horizontal area. The potential energy density is equal to the kinetic energy, both contributing half to the wave energy density E.

Max Wave Height Figures 18 and 19 from Wave & Wind Study

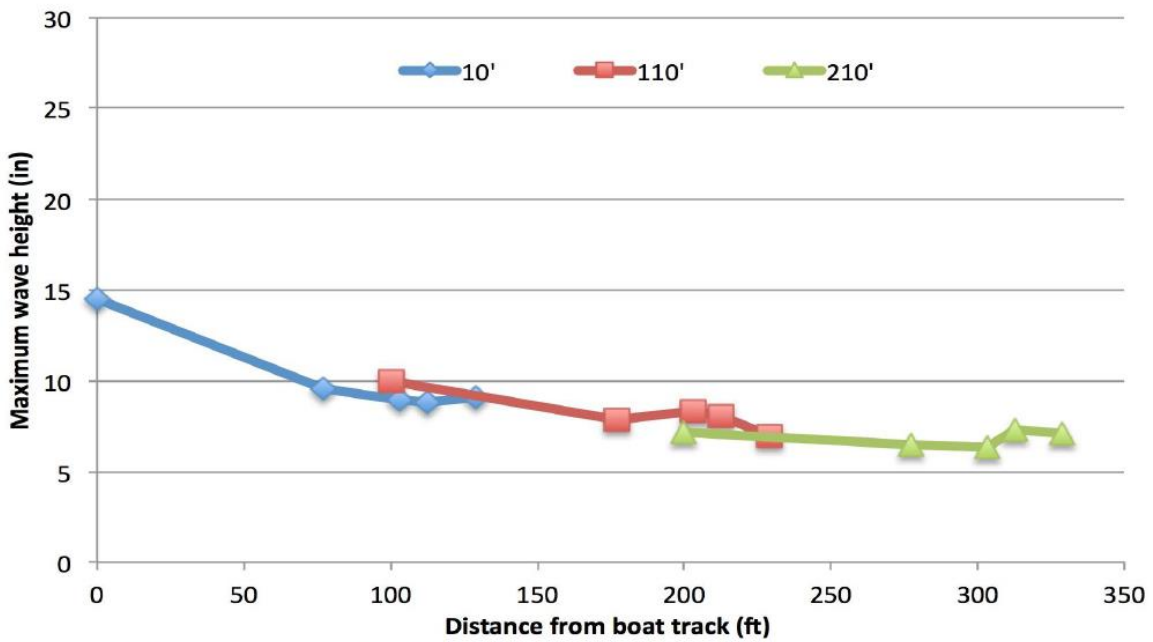


Figure 18. Maximum wave heights cruising at 25 mph in deep water at various standoffs.

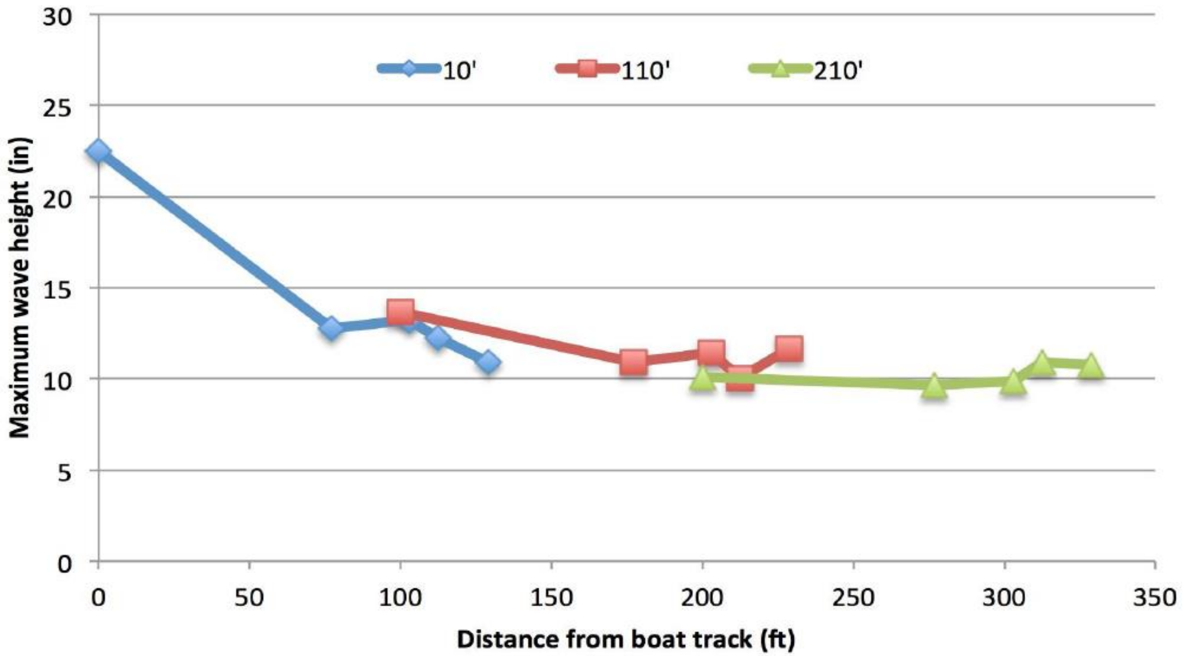


Figure 19. Maximum wave heights wakeboarding at 25 mph in deep water at various standoffs.

Note the increase in max wave height for further distances; the nature of test data is not precise since all variables cannot be controlled in the real world

Ref: (Draft Rev 2 (or 11???))
Characterization of Wake-Sport Wakes and their Potential Impact on Shorelines,
WATER SPORTS INDUSTRY ASSOCIATION (WSIA), November 2015

Data vs Trending

- This plot illustrates that the deep-water measurements less closely follow the trend line than the shallow water data and trend line. It is not clear from the report why this occurs. Some speculations are provided.

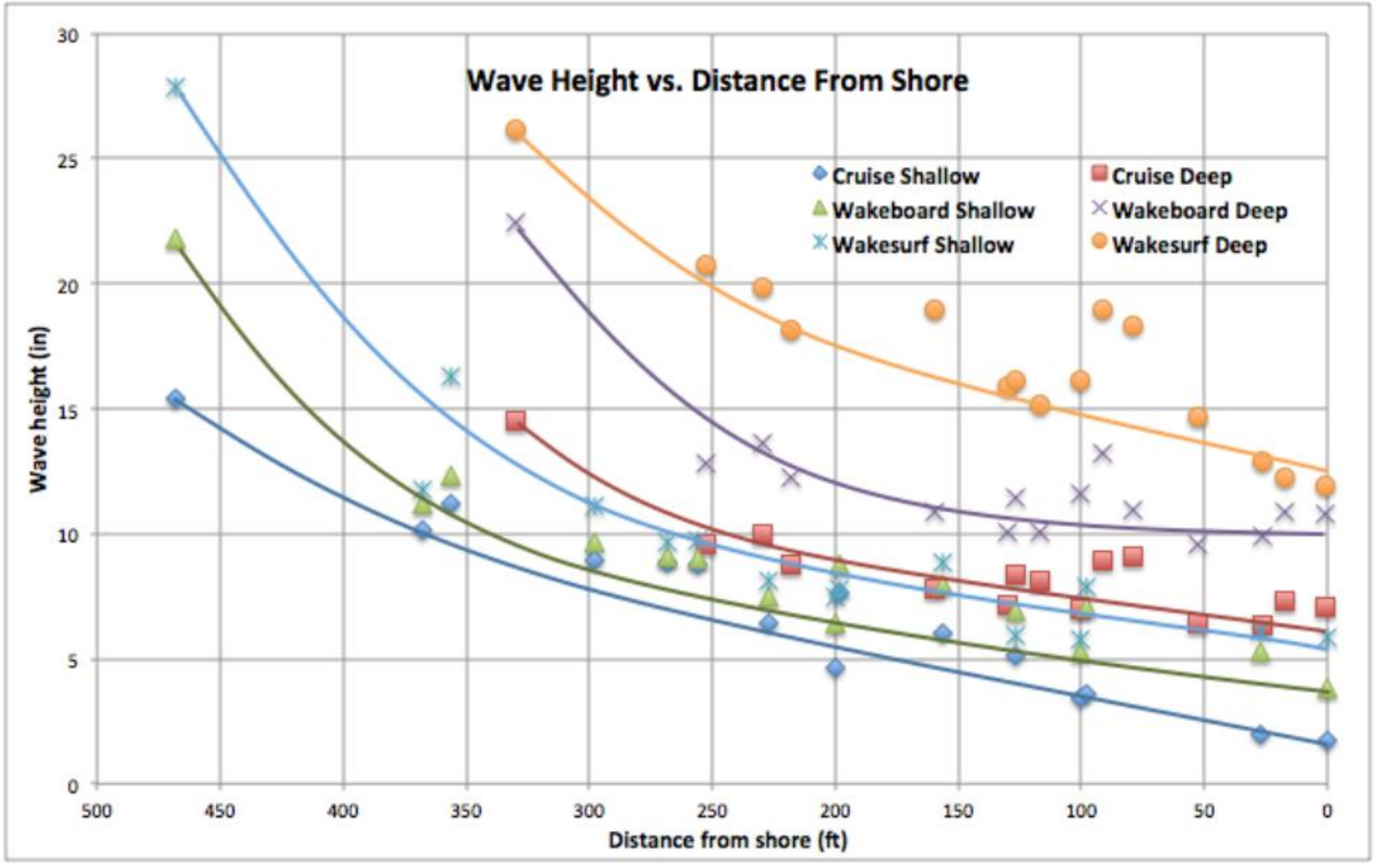
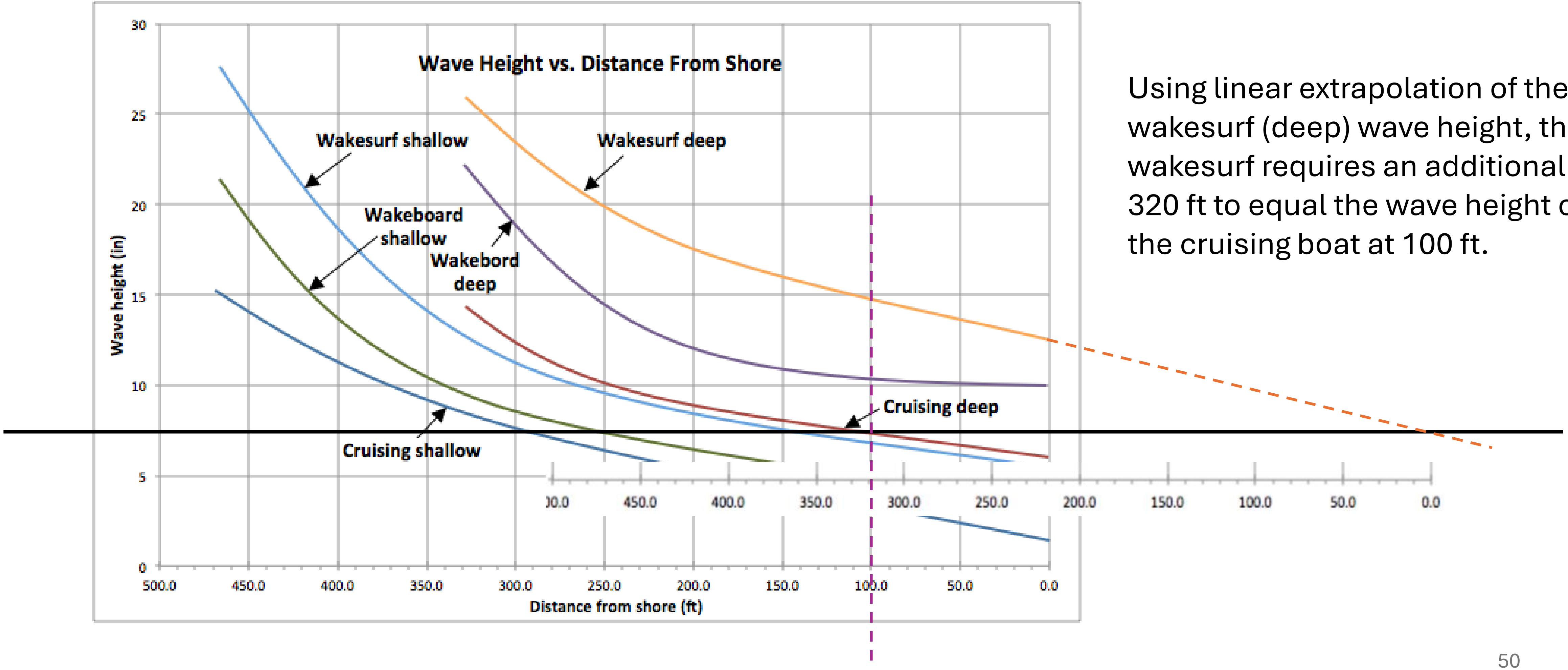


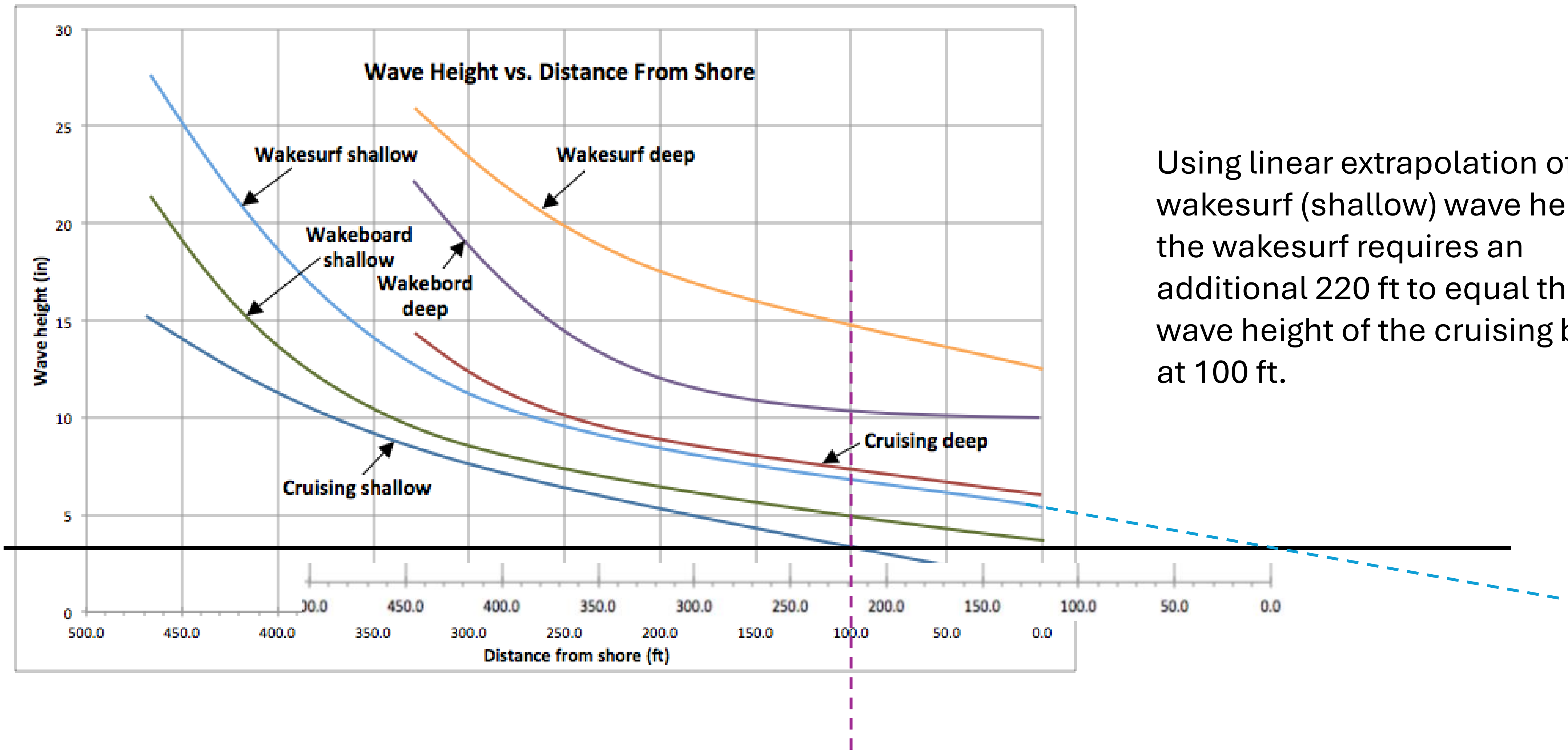
Figure 25. Wave height vs. distance from shore in shallow and deep water.

Wakesurf Distance to Equal Cruise Wave Height at 100' (Deep)



Using linear extrapolation of the wakesurf (deep) wave height, the wakesurf requires an additional 320 ft to equal the wave height of the cruising boat at 100 ft.

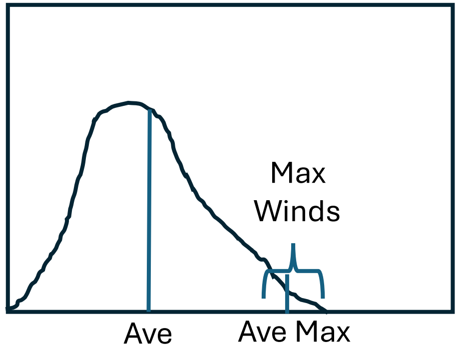
Wakesurf Distance to Equal Cruise Wave Height at 100’ (Shallow)



Using linear extrapolation of the wakesurf (shallow) wave height, the wakesurf requires an additional 220 ft to equal the wave height of the cruising boat at 100 ft.

Probability of Winds > 5 Mph On Sacheen Lake

- Generic wind (mph) probability illustrating the mean value. Graph matches Deer Valley airport mean and average max wind in nature (Ave Max = ~ 2x Ave)
- Probability of max ave winds is small (area of the curve in the “Max Winds” area)
- Wake surfing on Sacheen is not 24/7occurrence, neither are winds of 5 mph, even less probable are winds at 10 mph



Wind probability distribution chart (license protected) created during a study of wind for energy generation purposes is generically depicted as shown to the left

Ref: Distributed Active Power Optimal Dispatching of Wind Farm Cluster Considering Wind Power Uncertainty, April 2022

Additional Reading on Wind and Waves

- https://opentextbc.ca/geology/chapter/17-1-waves/#:~:text=As%20this%20happens%2C%20a%20point%20on%20the,equal%20to%20the%20wave%20amplitude%20(Figure%2017.3).&text=The%20wave%20%E2%80%9Corbits%E2%80%9D%20are%20both%20flattened%20and,wavelength%20decreases%20(the%20waves%20become%20much%20steeper)

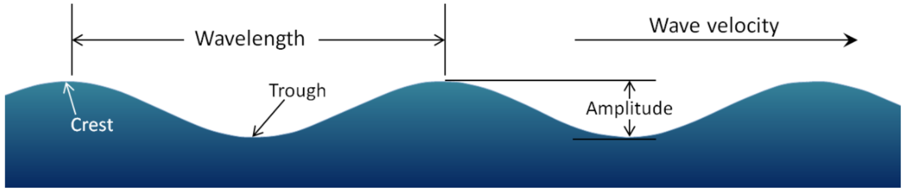


Figure 17.2 The parameters of water waves [SE]

Even though they bend and become nearly parallel to shore, most waves still reach the shore at a small angle, and as each one arrives, it pushes water along the shore, creating what is known as a **longshore current** within the **surf zone** (the areas where waves are breaking) (Figure 17.7).

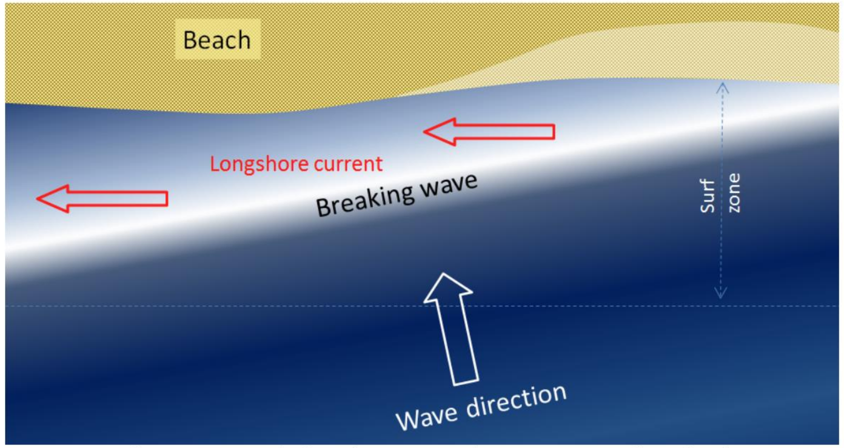


Figure 17.7 The generation of a longshore current by waves approaching the shore at an angle. [SE]

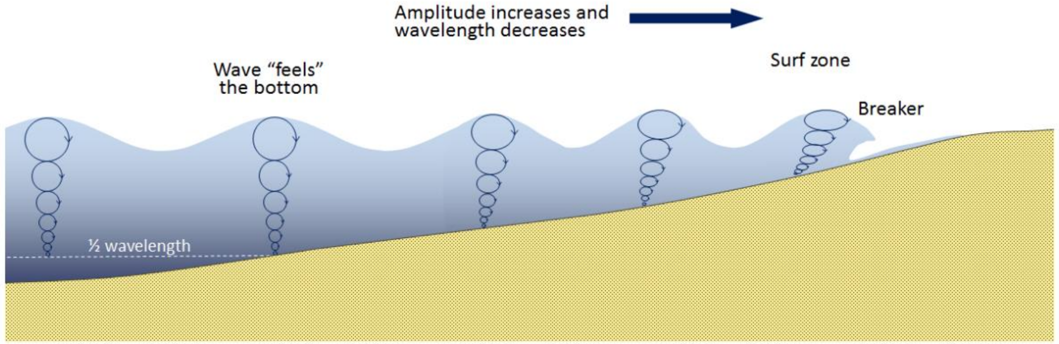


Figure 17.4 The effect of waves approaching a sandy shore [SE]

Wind Speed	Fetch	Duration	Amplitude	Wavelength	Wave Period	Wave Velocity	
km/h	km	h	m	m	s	m/s	km/h
19	19	2	0.27	8.5	3.0	2.8	10.2
37	139	10	1.5	33.8	5.7	5.9	19.5
56	518	23	4.1	76.5	8.6	8.9	32.0
74	1,313	42	8.5	136	11.4	11.9	42.9
92	2,627	69	14.8	212	14.3	14.8	53.4

Table 17.1 The parameters of wind waves in situations where the wind blows in roughly the same direction for long enough for the waves to develop fully. The duration times listed are the minimum required for the waves to develop fully. [SE from data at: http://en.wikipedia.org/wiki/Wind_wave]

Looking at the first row

- 19 km/h wind = 11.8 mph
- 19 km fetch = 11.8 miles
- At least 2 hours of steady wind is required
- 0.27 m height = 10.6 inches
- 8.5 m wavelength = 27.9 ft
- 10.2 km/h wave velocity = 6.3 mph