Four critiques of recent study sponsored by National Marine Manufacturers Association

Numerical Study of the Impact of Wake Surfing on Inland Bodies of Water

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Review by Gregor Macfarlane (gregorm@amc.edu.au):
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According to the title of this paper, the implied focus is on the impact of wake surfing on sheltered waterways. Numerical techniques are the primary method adopted to perform the study.

In the Abstract it is stated that this paper:

- quantifies the impact related to turbidity and erosion with the use of computational fluid dynamics (CFD) of boat wakes in shallow water and the build-up of wind driven waves.
- quantitatively describes the energy, type and direction of the boat's wake and a table for predicting wind driven waves over varying fetches, depth and wind speeds is provided.
- Shows, using CFD simulations, that if a wake surf boat is operated 200 ft from shore and in at least 10 ft of water, the environmental impact is minimal.

My review of each of these dot points can be summarised as follows:

- Limited details have been presented of a numerical (CFD) study to investigate the potential depth that boat propeller wash may extend below the boat, where it is recommended that the water depth be at least 10 feet for wakesurfing operations (it is claimed prop wash does not extend this deep). However, there has been zero attempt to investigate the impact that boat waves may have on shoreline erosion or turbidity at the river/lake/sea bed, despite the opening sentence of the Abstract acknowledging that "wakesurfing has been cited as one of the major causes of lakeshore erosion and turbidity". As for wind generated waves, the authors have adopted standard equations to estimate their characteristics, but the value of any comparison against boat generated waves is questionable.
- The paper may have attempted to quantitatively describe "the energy, type and direction of the boat's wake and a table for predicting wind driven waves over varying fetches,

depth and wind speeds", but I don't believe any of this actually addresses the stated aim of the paper to quantify the impact of wakesurfing on inland bodies of water.

- It is drawing a very long bow to claim that the CFD simulations presented in this paper show that the environmental impact is minimal when a wake surf boat is operated 200 ft from shore and in at least 10 ft of water. As alluded to in the first dot point, this paper has not presented any material that investigates the environmental impact caused by any aspect of wakesurfing.

I've provided additional commentary on each section below.

Abstract
As noted above, the final sentence in the abstract is incorrect and misleading.

Section 1 Introduction
This opening section provides a useful introduction to the sport of wakesurfing. In the second paragraph it is stated that the "purpose of this study is to examine the actual impact of wake surf boats on the shoreline and water bottom using computational fluid dynamics (CFD)". The impact on either the shoreline or bed has not been investigated.

There is a basic introduction to CFD and its application in the marine industry. The importance of validating CFD results is acknowledged, and although the studies referenced are relevant, simply referring to them does not provide any level of proof that CFD will provide reliable data in all applications. From my experience, the application of CFD to accurately simulate boat generate waves in anything other than the very near-field (ie. close to the hull) has been very challenging. For the present study the interest is very much in the medium- to far-field (in the order of 200+ feet from the sailing line, as mentioned in the Abstract). The vast increase in domain size (volume) to be modelled in CFD can be highly problematic. In addition, the validation of CFD to accurately represent wave dispersion and attenuation is essential, as even small errors can and often do produce wildly different results.

Section 2 Boat Generated Waves
I have no great issues with some of the initial material introducing boat generated waves (although the constant misspelling of 'planing' is annoying). Much of the material contained from mid-way through Page 241 to the end of this section (Page 247) is irrelevant to the stated nature of this study, so I don't see what value it brings the paper. It certainly doesn't lead to any useful conclusions. The calculations also appear to involve a number of assumptions that could significantly affect the end result (for example the overall efficiency due to the "propeller cavitating badly").

It is hard to justify this approach against the direct measurements of the waves generated during semi-controlled full scale trials, as performed in the SAFL, WSIA and AMC/ORSPA studies.

It is useful to have a basic understanding of the wave patterns generated by moving boats, especially as the pattern can change dramatically with speed and water depth. However, the material on wave angles is lacking key and relevant details. It is also confusing when this section starts by referring to the planing craft seen in Figure 2, which is clearly operating at a supercritical speed where the wave pattern is vastly different to the one depicted in the text and Figure 6 (which has the boat operating at sub-critical speeds).

Section 3 CFD Analysis of Wake Surf Boat
The majority of the material presented in Sub-Sections 3.1 and 3.2 provide typical background details on the CFD simulations performed. For such studies it is common to include a grid- or mesh-dependence study (or similar), but none is provided. Figure 13 shows the convergence over time for the vertical force on the hull in shallow water, but I don't see the relevance of this.

I generally find the most useful 'raw' data for wave wake studies to be time series records of the water surface elevation – such as the examples included in Figures 22 to 24 showing sections at different lateral locations relative to the sailing line of a wakesurfing boat at 12 mph (and further examples in Figures 25 to 30). This is a useful outcome, provided the predictions are validated against reliable data (usually experimental data). This is presumably a subject of the next section.

Section 4 Experimental Field Data
Some of the material contained in the opening two paragraphs seem a bit out of place and just confuse the issue as their relevance to the present study is unknown. The experimental data presented in this section is sourced solely from Goudey and Girod (2015), a non-peer reviewed and unpublished report sponsored by the Water Sports Industry Association (WSIA). I have independently reviewed this report and, although much of the experimental data presented appears to be reliable and generally in line with other similar studies, I have concerns with some of the interpretation and claims made in that paper. Some of the experimental data from the WSIA study has been presented in this section, presumably in an attempt to validate the CFD simulations (although this is not specifically stated). However, no direct comparisons of data are made and key details are either missing or difficult to extract, thus questioning the value of the exercise. The comparisons between the WSIA measurements and CFD predictions is made even more general in nature because the lateral distances for each of the sensors in the WSIA report are not stated in the current study.

On Page 259 it is stated that the "wave heights, period, and shape of the wave train match well", presumably referring to the experimental data in Figure 25 and CFD predictions in Figures 26 and 27. In my view, there are too many differences in a number of key variables to make anything more than very general conclusions from the very simplistic comparisons.

Reference is also made to "plotted wave profiles from [5]" which refers to Bilkovic et al. (2017), but this paper does not present any such plots – presumably this reference is made in error?

It is stated near the top of Page 258 that the "resolution near the boat is good but deteriorates at more than three boat lengths away from the boat making it impossible to plot the expected wave height more than 100 feet from the track of the boat". This raises further questions as to how the authors can claim (in the Abstract) that the "CFD simulation shows that if a wake surf boat is operated 200 ft from shore and in at least 10 ft of water, the environmental impact is minimal".

The amount of high frequency noise in the CFD results is unusual and at times excessive. The potential sources of this noise is not discussed.

Section 5 Wave Energy Attenuation
The attenuation of waves over lateral distance is often a key aspect of any study attempting to quantify the characteristics of boat generated waves in sheltered waterways with sensitive shorelines. However, the material presented in this section is poorly explained and its relevance to the aims of the paper is questionable (and can be misleading).

Section 6 Turbidity
This section presents some details on the CFD study that attempts to simulate the wash/jet from the propulsion unit (propeller). At best, the investigation estimates the potential depth that boat propeller wash may extend below the boat, from which the authors suggest "the recommended depth for wake surf operation is conservatively set at 10 ft" (in the Abstract the authors make the more appropriate recommendation that this be "at least 10 ft"). The paper does not consider the effect that the propeller wash may have on the river/lake/sea floor or turbidity.

Section 7 Wind and Waves
The standard wind wave equations presented in the US Army Corps of Engineers Coastal Engineering Manual (2015) have been used to generate the characteristics of wind generated waves. It appears the authors have adopted CFD to extrapolate this to shorter fetch distances.

The reasons for including this material is not stated, but it is assumed the authors intend to compare the characteristics of boat and wind generated waves. In my experience this is almost always a flawed exercise: shorelines are generally dynamically stable and formed according to the naturally occurring waves generated by the prevailing wind conditions. In contrast, boat generated waves are discrete events and if they exceed the local erosion thresholds, they will result in erosion. If this occurs repeatedly, the shoreline will become dynamically unstable and continue to erode.

I don't understand why none of the values quoted in the text (bottom of Page 267) correspond to the values on Table 4.

Section 8 Conclusions
The authors have strayed from the scientific standard of never introducing new material in the Conclusions section. This is a little frustrating, as some of the new material (including discussion) may have helped explain the relevance of some sections had it been alongside.

Regardless, this study fails to provide the material and evidence from which to make any sound conclusions. It does make the bold statement at the very outset that "The report has shown that the operation of wake boats on a lake has a minor impact on the environmental health of the body of water". It does not show this at all.4 The Conclusions section then references other (relevant) studies, such as Glamore (2008) and Parnell (2001), and appears to combine this with other (often irrelevant) material (such as what relevance Equation 19 has in this context). It is unclear where the value of the so-called "agreed" maximum wave height of 28 cm (11 inches) has come from, or how this was determined?

It is also claimed that the field test data from Goudey and Girod (2015) found that a distance "of 200 feet to be adequate to reduce the wave heights to under 28 cm (11 inches)"; and that both Goudey and Girod (2015) and Glamore (2008) suggest "a distance of 200 feet allows the wave train to dissipate enough to cause little or no impact on the shoreline. I have reviewed both of these articles in detail and this is blatantly incorrect in both cases. In the same paragraph it is also claimed that Glamore (2008) observed that the wake from a wakesurf boat "will dissipate completely in 300 metres from the boat path while operating in deep water" – this too is untrue. It appears that the authors rely very heavily on these false claims to make their unsubstantiated conclusions.

Several sources provide examples that confirm that a distance of 200 feet in clearly inadequate for reducing the height of the waves generated by wakesurfing boats to under 28 cm (11 inches). This includes the full scale trials data presented by Goudey and Girod (2015) in their Figure 27, which shows the maximum wave height at wakesurfing speed (~11 mph) is approximately ~12.5" at the greater lateral distance from the boat track of ~330 feet. At a lateral distance of 200 feet the average maximum wave height is closer to XX", well above the 11" claimed in this paper.

The experimental data presented by Goudey and Girod (2015) is in approximate agreement with other recent studies that have adopted the approach of directly measuring the waves generated by wakesurfing craft during full scale trials. For example, the recent University of Minnesota study (St. Anthony Falls Laboratory, SAFL, 2022) and the AMC/ORSPA study from the Willamette River (Macfarlane, 2018).

Section 9 Epilogue
The issue of imposing restrictions on activities such as wakesurfing is raised.

General Comments
The purpose or aims of each section is not explained, nor is there a clear process or link between sections. The end result is a very disjointed document that fails to present even a hint of a convincing case.

The paper does not present any new or novel material, no noteworthy conclusions, and nothing worth referencing.

It is hard not to question the motives of publishing this paper, especially when some of the statements made in the Abstract and Conclusion are clearly not supported by the material presented in the body of the paper.

From what I can see, none of the Authors have previously published any peer-reviewed studies involving boat/ship generated waves, or hydrodynamics. The Authors appear to be experienced practicing engineers (including CFD in the case of authors #2 and #3) but again there does not appear to be any track record of applying CFD to simulate boat/ship generated waves.

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It is not a technically sound paper. The fact that they model a 7 second period wake for a "free running" boat is obviously wrong. When a waterski boat goes by, when have you ever seen 7 seconds in between the successive wake waves that reach the shore? Waterskiing conditions create wake with shorter wave periods than the wake surfing conditions, as demonstrated by *measured* data.

The model is not calibrated or validated. Typically models are directly compared to measured data and error statistics are calculated to give the investigator an idea of model accuracy and uncertainty. That was not done in this case, and as a result one can't have any confidence that the model is suitable for evaluating the problem.

There is no need for CFD modeling to evaluate the problem. I often use numerical modeling on projects, and it can be a useful tool to evaluate many problems where one wants to compare hypothetical conditions (e.g., if we build a new breakwater, how large will the wave heights be inside the marina basin?). In this case, we don't need a model, because we can directly measure the wakes from various boats, and measured data are preferable to model data (given model limitations, uncertainties, etc.).

The abstract says "The CFD simulation shows that if a wake surf boat is operated 200 ft from shore and in at least 10 ft of water, the environmental impact is minimal" but they don't really demonstrate that this is true. The problems caused by boat wakes are related to safety, structural damage, shoreline erosion, disturbance of bottom sediments, poor conditions for other users (paddlers, fisherman, etc.), etc. Their vague assertion about minimal environmental impact is meaningless.

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Review by David Johnson – Responsible Wakes for Vermont Lakes

1. The paper describes a numerical simulation of wake boat waves and of the prop wash from wake boats. The simulation looks to be well constructed and is able to **qualitatively** reproduce experimental observations of wave behavior.
2. From the numerous misspellings, referencing mistakes, and other inconsistencies, this manuscript was not rigorously reviewed. The publicly available literature is inadequately referenced. Relevant comparisons to other studies are not quantitative when they could be. The publisher has a questionable reputation regarding scientific standards and peer review process.
3. The assertion -- "if a wake surf boat is operated 200 ft from shore and in at least 10 ft of water, the environmental impact is minimal" -- is not adequately justified by the simulation results presented. See below (see 6,7) why the comparison with wind-induced waves as a justification for the 200 ft distance is invalid, and (see 5) for why the results for the penetration of the prop wash to justify the 10 ft depth is also invalid.
4. While both CFD and experimental results show the same qualitative attenuation trends, the absolute wave heights are quite different. For example, the 2015 Goudey study measured wave heights of 27” vs 20.5” (in the simulation) at 16’; and 20” vs 9.4” at 66’ for wakesurfing and 21” vs 20.5” at 16’ and 16” vs 11” at 66’ for wake boarding. (Based on figures 16 and 17 of the 2015 Goudey study). Also, there have been several other studies measuring wave heights using pressure sensors, that were not mentioned or included in the list of references.
5. The lowest velocity contour shown in the prop wash figures 33-36 is 14 mph (6.25 m/s). No basis is given for this choice of velocity limit. Velocities as low as 0.25 m/s can resuspend fine sediments. Extending the range of velocities displayed in these figures to these more relevant lower values would show much deeper penetration. Other similar simulations indicate that they would extend to >30’. (Alex Ray)
6. This choice of 11” as a tolerable wave height seems arbitrary. While reference 8 indicates a wave height "28 cm measured 300 m from sailing line in deep water" as a wave management criterion, the authors embrace the 28 cm but not the 300 m distance. Also, the criterion is meant to apply to coastal and inland waterways, not small Vermont lakes. It is one of many suggested management criteria cited in reference 8. It does not consider the fact that in addition to extraordinary wave heights, waves from wake sports also have longer periods compared to traditional motorboats, meaning that the energy and power in the waves is considerably higher. We feel a better basis of comparison for regulation in Vermont is the wave height from ski boats at 200’, since this is the wave height that Vermont lakes have been subjected to for

decades. This wave height, according to the UMN study, is 6". Even more relevant for shore erosion is the maximum wave power. To make the maximum wave power equivalent to that from a ski boat at the present regulatory shoreland protection distance of 200', the wake surfing must be over 1000' from shore, according to predictions from the UMN study.

7. "In comparison to wind generated waves, the wave height of 28 cm is common in a modest wind event on lakes with a fetch of a half mile (0.8 km) at a wind speed of 20 mph (9.0 m/s)." As Dr. Yves Prairie has demonstrated, sustained 20 mph winds are extremely rare and not "modest wind" events on inland lakes. And even if they were common, such high winds normally are associated with a small range of wind directions. Inland lakes feature sections of shoreline that are nearly always protected from these high winds and hence vulnerable to wakes from boats operating too close to shore.
8. "In a study, it has been observed that a wake-surf boat wake will dissipate completely in 300 meters from the boat path while operating in deep water [8]." I was unable to find this result in reference 8.

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Review by Prof. Yves Prairie (prairie.yves@uqam.ca)
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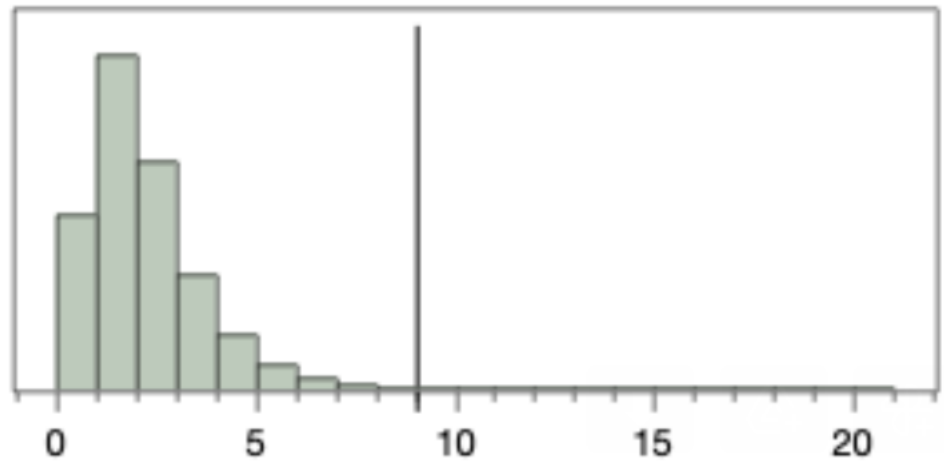
The authors write:

"Based on both the field data and CFD data, the key to reducing the impact of wake surfing is to operate the boat far enough offshore to allow the wake neat the boat to dissipate into its component parts where the individual wave heights of the group are reduced to a height less than 28 cm (11 inches). The field test data [4] found 200 feet to be adequate to reduce the wave heights to under 28 cm (11 inches). In comparison to wind generated waves, the wave height of 28 cm is common in a modest wind event on lakes with a fetch of a half mile (0.8 km) at a wind speed of 20 mph (9.0 m/s). The full wave spectrum would be fully developed in less than 20 minutes and the average wave period would be 1.5 seconds."

They used this threshold of 9m/s stating that this is a common thing. This is completely false. A wind of 9m/s is exceedingly rare. Here is a histogram of 2 million hourly wind data from about 230 lakes/reservoirs and a wind greater or equal to 9 m/s only occurs about 0.25% of the time, so ¼ of 1 percent. Even that is probably exaggerated because large winds basically only occur in large lakes. For the vast majority of lakes (say 90%), winds >9m/s occur less than 0.1%, so a tenth of 1%. That's hardly common…



The vertical line is the 9 m/s.

One last thing. The simulations seem to ignore the fact that, during the summer, lakes are not well mixed but instead will consist of a warm upper layer and a cold bottom layer. These two layers are separated by a strong density gradient that a wave won't really disturb (minimally anyway) so that the energy contained in the wave can only dissipate laterally and not to the bottom until it reaches shallow enough areas, thereby disturbing shallow sediments and the shore.