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SEAPLANE NOISE

by Aron Faegre

December 15, 1995
(Revised September 10, 2002)

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TABLE OF CONTENTS

1.0 Introduction . . . . Page 1

2.0 Summary . . . . Page 1

3.0 Seaplane Noise Generation . . . . Page 2
- 3.1 Take-off & Landing Profiles . . . . Page 2
- 3.2 Origin of Noise . . . . Page 3
- 3.3 Noise Propagation . . . . Page 4
- 3.4 Noise Impact . . . . Page 5
- 3.5 Conclusion . . . . Page 6

4.0 How Much Noise is Too Much . . . . Page 6

- 4.1 Neighborhood Compatibility . . . . Page 8
- 4.2 Noise Measurement . . . . Page 8
- 4.3 Frequency of Sound . . . . Page 9
- 4.4 Yearly Averaged Sound Level . . . . Page 9
- 4.5 Sample Calculation . . . . Page 10
- 4.6 FAA Part 150 Noise Compatibility . . . . Page 12
- 4.7 Other Airport Noise Metrics . . . . Page 17
- 4.8 FAA Certificated Noise Levels . . . . Page 18
- 4.9 Noise Level Descriptors not Used for Aviation . . . . Page 18
- 4.10 Taking Noise Measurements . . . . Page 19

5.0 Seaplane Noise Abatement . . . . Page 19

- 5.1 Take-off Noise . . . . Page 19
- 5.2 Fly-over Noise . . . . Page 20
- 5.3 Minimizing Noise . . . . Page 20

6.0 How to Deal with a Complaint . . . . Page 21

7.0 Conclusion . . . . Page 23

Tables:

Table 1: Seaplane Noise Levels . . . . Page 3
Table 2: Noise Level Thermometer . . . . Page 7

Figures

Figure 1: Propeller Noise Directivity . . . . Page 4
Figure 2: Seaplane Takeoff Noise . . . . Page 6
Figure 3: Integrated Seaplane Takeoff Noise . . . . Page 11
Figure 4: Noise Contours: Taylorcraft @ 52 flights/yr . . . . Page 13
Figure 5: Noise Contours: Stinson @ 52 flights/yr . . . . Page 13
Figure 6: Noise Contours: Cessna 206-3B @ 52 flights/yr . . . . Page 13
Figure 7: Noise Contours: Cessna 185-2B @ 52 flights/yr . . . . Page 14
Figure 8: Noise Contours: Cessna 185-2B @ 365 flights/yr . . . . Page 15
Figure 9: Noise Contours: Cessna 185-2B @ 1000 flights/yr . . . . Page 16

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1.0 Introduction

It is fortunate for seaplane enthusiasts that seaplanes do <u>not</u> in general have a major environmental noise problem to solve. Rather, it is major commercial airports in our large urban areas that have the big problems. In many of our principal commercial airports there is significant conflict between the large commercial and military jet aircraft and adjacent residential areas.

In the case of seaplanes, the operations generally consist of smaller and lighter aircraft operating with less frequency and less concentrated use. Non-commercial seaplane bases or water landing areas may have only several operations per week rather than several thousand operations per week at a major urban airport.

Also, because seaplanes do not utilize a specific runway, and can use large portions of lakes, rivers, and bays for take-off and landings, the operations are usually not concentrated in one particular location, as they are for most land-based runways. Thus the flight paths change slightly depending on wind direction and intensity, and pilot preference. The result is that seaplane sounds tend to be more spread out and not concentrated at one specific runway site.

Although in the larger scheme of things seaplanes do not have a big problem, the noise from seaplane operations does sometimes annoy and disturb people. This may be because of the intensity of the sound, such as if it interrupts conversation or wakens someone from sleep. However, more often those who object to seaplane noise just find it an objectionable annoyance. They don't like it and they question whether the seaplane pilot has a right to fly on the waterway. They may use the noise issue as a method to try to get rid of the seaplanes. The noise may be the trigger of their fears of aircraft flying over their house rather than the noise.

The materials in this report will help the seaplane pilot deal with both major and minor seaplane noise problems. Noise standards created by federal law and intended to determine compatibility between airports and communities are described in detail. These should be used as the ultimate determinants of whether a type and level of seaplane activity should be considered legally acceptable as it relates to noise impact. In addition, seaplane noise abatement procedures and methodologies are discussed. These should be especially helpful for cases where seaplanes are not technically violating any accepted FAA noise standards, but are an annoyance to some individuals.

2.0 Summary

The purpose of this study is to provide information for the seaplane pilot to make their case to citizens or local authorities who are concerned about seaplane noise. This is a primer of information on the issue of seaplane noise and its impact on other land uses. The information in this study consists of:

- o An initial description is provided of the factors that influence the amount of noise created by a seaplane, how that noise is propagated through the air, and how the noise impacts adjacent land uses.

- o Detailed information on the technical methodologies for determination of noise impact are then provided. Standard noise descriptors are described that integrate the sound impacts from multiple aircraft flights in order to create cumulative or averaged sound level impacts.

- o Regulatory aspects of seaplane noise are discussed. It is shown that airport noise impact standards approved jointly by FAA, HUD, EPA, DOD, and the VA utilize integrated noise levels which can be used to determine actual seaplane noise impact by standard mathematical computation.

- o Sample calculations of noise impact are provided for differing types of seaplanes and amounts of use.

- o A discussion of noise abatement methodologies, as they relate specifically to typical seaplane operations, are discussed; and

- o Finally, there is a brief consideration of how to deal with a complaint when the pilot receives one.

The good news is that when compared to the typical airport noise problems at our major urban centers, seaplanes are a relatively minor consideration. If the seaplane is small, and the number of operations is modest, it can be completely compatible with any waterway as its noise level will be similar to that of outboard motors, jet skis and other common waterway sounds. Medium sized seaplanes such as Cessna 185 and 206 can be compatible with a relatively small area as long as the numbers of operations are small.

3.0 <u>Seaplane Noise</u>

3.1 Take-off & Landing Profiles

Most aircraft make their greatest noise on take-off, since it is at that point that a large amount of thrust is required to become airborne. In a seaplane, take-off is generally accomplished at full power in order to rapidly get up onto the step and then off the water to clear waves, swells, debris, or other water-related complications. After lift-off, normal procedure is to level off until reaching best angle of climb Vx or best rate of climb Vy. Many pilots then maintain full power until up to a safe altitude, as many believe there is some history of power failures occurring at the time of power reduction. Thus, the normal seaplane take-off is at full power from start of take-off run until reaching an altitude of 500 feet.

The landing profile typically consists of an overflight at 500 feet AGL at a reduced power setting to view the landing area, followed by a major reduction in power during the approach. The typical landing involves the addition of some power prior to touch-down in order to add airflow to the tail control surfaces, which in turn adds maneuverability for increased landing safety purposes.

The reduction of power during landing is so great when compared to take-off, that for the purposes of this article, noise during take-off will be the sole consideration in terms of computed noise impact. In fact, seaplane noise levels at low throttle settings are generally below background noise levels and thus are not measurable. An overflight at 500 feet with cruise power can constitute a measurable noise impact and consideration of that phase of flight will be covered when discussing noise abatement. However, because take-off constitutes the phase of flight which produces the most noise and has the least flexibility for pathway, this study will primarily focus on seaplane take-off noise impacts.

3.2 Origin of Noise

The majority of the noise coming from a propeller aircraft is created at the tips of the propeller; there is not much coming from the exhaust pipe. Technical studies have shown that the noise output from a propeller-driven aircraft is determined principally by the propeller tip Mach number (tip speed related to speed of sound at the existing air temperature) and the horsepower input to the propeller. The noise output is also affected by the number of blades and propeller diameter, but these are lesser factors.

Generally, a 10% reduction in horsepower by only reduced throttle (i.e. from 30" MP to 27" MP, but RPM's unchanged) results in a decrease in the sound level output by 0.8 dBA. Likewise a 10% reduction in horsepower by only reducing RPM (i.e. from 2800 RPM to 2520 RPM, but with MP unchanged) results in a decrease in the sound level by 6.9 dBA. Finally, a 10% increase in distance between the seaplane and the noise sensitive source results in a decrease in the sound level received by 1.0 dBA. This shows that to reduce seaplane noise that RPM reduction is to some extent the <u>only</u> important factor. In fact, to gain an equivalent 6.9 dBA reduction by throttle alone, one would have to reduce power by 60%, which is not really an option during takeoff. Likewise, to gain an equivalent 6.9 dBA reduction by distance alone, one would have to more than double the slant distance between the seaplane and the noise sensitive use. This is possible in some cases, but not in others.

Samples of maximum noise levels of various aircraft are given below, at a standard distance of 1,000 feet during takeoff. Measurements were in a river valley setting, so in larger water areas the noise levels may be slightly less.

Seaplane Noise Levels

Type	hp	Propellers	Lmaximum @ 1000'
Taylorcraft	85	2	65 dBA
Seabee	215	2	81 dBA
Stinson	250	2	82 dBA
C-180	235	2	86 dBA
C-206	300	3	88 dBA
C-185	300	2	92 dBA

The next greatest factor in seaplane noise is the directional nature of the noise relative to the seaplane. The intensity of sound is greatest off the tips of the propeller, at approximately 105 degrees from the front of the aircraft, in other words 15 degrees aft of the wing tips. In the forward direction, the noise level decreases by about 7 dBA up to 30 degrees off the nose, and then decreases very rapidly beyond that. In the aft direction the sound levels decrease much more rapidly, decreasing 12 dBA once reaching 160 degrees aft of the nose (70 degrees aft of the wing tip). Thus, directly in front of or behind the seaplane there is considerably less noise than horizontally beside it.

Figure 1 below shows the typical change in sound level relative to the angle between the aircraft and the observer.

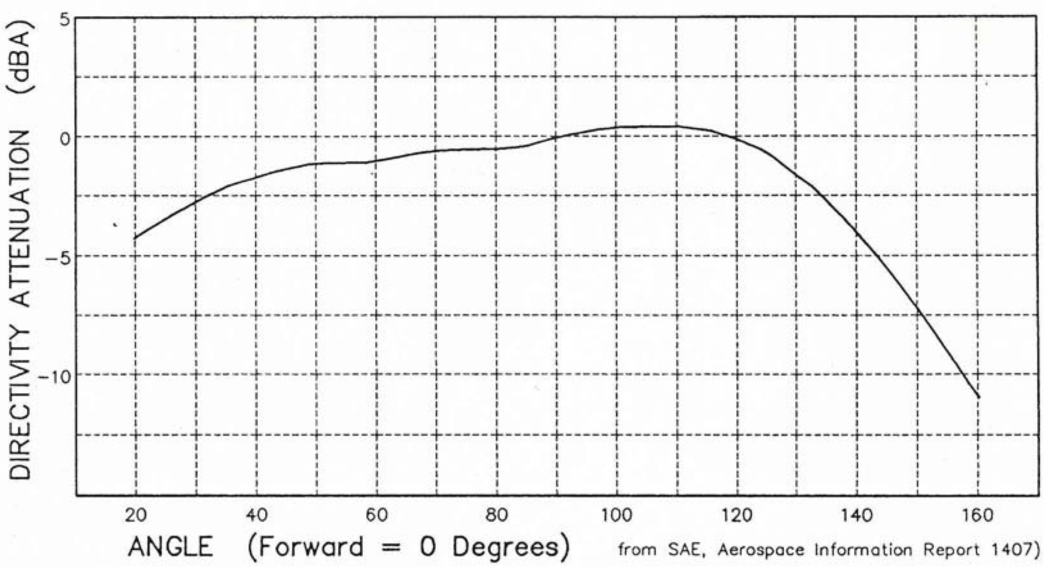


FIGURE 1: PROPELLER NOISE DIRECTIVITY

The sonic-speed shock wave noise of the propeller can be a dominant source of takeoff noise from a seaplane. This sharp increase in noise output occurs when the propeller blade gets into the range of .9 to .95 Mach (depending on type of propeller). Three-bladed propellers make less noise than two-bladed propellers. This is because the power delivered by the engine at a given RPM can be converted to thrust by a smaller diameter three-bladed propeller than the two-bladed propeller, thus the noise generating propeller tip speed is lower and quieter. Kenmore Air Harbor's experience is that the three-bladed prop reduces the noise impact from a Cessna 185 or 206 by 5 to 6 dBA for McCauley propellers. Our data also confirms this reduction.

The Hartzel Q-tip propeller is sometimes thought to be available as another noise reduction option. The Q-tip propeller has the tips turned back to reduce the airflow off the end of the tip, much as winglets do for the wing on some modern aircraft. Hartzel does not make a claim of noise reduction, however they believe the Q-tip allows use of a replacement propeller that is 2" less diameter than that for its equivalent. Thus at the same RPM, it has the same thrust as a propeller 2" greater in diameter. It obviously achieves this at somewhat less tip speed which in fact must result in less noise impact. The effective shortened dimension and reduction in vortices off the tip reduce the problem of water and cavitating the propeller, which is probably the more significant role of Q-tip props for floatplanes. We look forward to gaining data on the Q-tip propeller to verify the noise reduction capabilities.

3.3 Noise Propagation

Due to the inverse square law, the sound level from a seaplane decreases in intensity as the aircraft increases in distance from the source. Depending on atmospheric and geographic conditions, there is generally a 3 to 7 dBA (say an average of 5 dBA) decrease in sound level for each doubling of distance. Thus if a seaplane creates an 87 dBA impact at 1,000 feet, then as a rule of thumb it will create an 82 dBA impact at 2,000 feet or a 92 dBA impact at 500 feet These are approximate numbers, and geographical features such as hills, cliffs, and adjacent vegetation, as well as strong winds, can have a large effect on sound level.

It is important to note here that distance between seaplane and observer is significantly less a factor than the type of aircraft. For example, a Stinson floatplane with 250 hp Franklin engine at 1,000 feet might typically create an 82 dBA maximum noise level. It is clear that even in the most advantageous of conditions, the Stinson would have to be 5,000 to 6,000 feet away to get the sound level down to the 65 dBA of a Taylorcraft 85 hp floatplane at 1,000 feet. Thus, distance is important as an attenuation factor for seaplanes, but the type of seaplane and propeller RPM's remain much more significant factors.

Besides attenuation due to distance, vegetation can occasionally be a significant factor. If thick grass and shrubbery, or thick forests, exist along the water's edge, and noise sensitive houses are well back within the vegetation, the plants may provide additional attenuation of the sound. The amount of attenuation can be in the range of 5 to 10 dBA per 300 feet of dense vegetation. Very thick forests have on occasion been shown to provide up to 25 dBA of reduction for a 300 feet depth. However, bare deciduous trees during spring, winter, and fall will provide no attenuation whatsoever.

In the water environment, the seaplane does not usually get the help of significant vegetation absorption between the pathway of the seaplane and the observer. The amount of attenuation will generally be very small unless the plant material is very thick and the residences are located far away from the water's edge. In reality, residences usually try to locate with a good direct view of the water rather than hidden behind several hundred feet of thick vegetation. Thus, the type of aircraft and distance from observer remain the most significant aspects of seaplane noise analysis.

3.4 Noise Impact

In our discussion so far, the noise has been created by the seaplane, has propagated some distance, and it has been attenuated to a lower dBA reading. It then reaches the observer. At waterfront locations it is common to have outdoor decks, patios, and docks so there is generally no way to "hide" behind walls or hedges from the noise impact.

Figure 2 below shows an overlay of sample noise level readings from three different seaplanes on take-off, at a deck overlooking the author's river residence. In each case the seaplanes were approximately 1,000 feet from the noise meter. Since there is no runway center line for seaplanes, distances are more difficult to determine than for land planes. However, because the distances are believed to be accurate within 20%, the noise level readings are therefore accurate within 1 or 2 dBA.

It is obvious that there is a great difference in sound impact depending on the type of aircraft. The little two-seat Taylorcraft with 85 hp engine has a maximum sound level of 65 dBA, whereas a Cessna 185 with 300 hp engine and two-bladed propeller reaches a maximum of 92 dBA. A Cessna 206 with 300 hp engine and three-bladed propeller has a maximum of 88 dBA. A Stinson with a 250 hp engine has an 82 dBA maximum noise level.

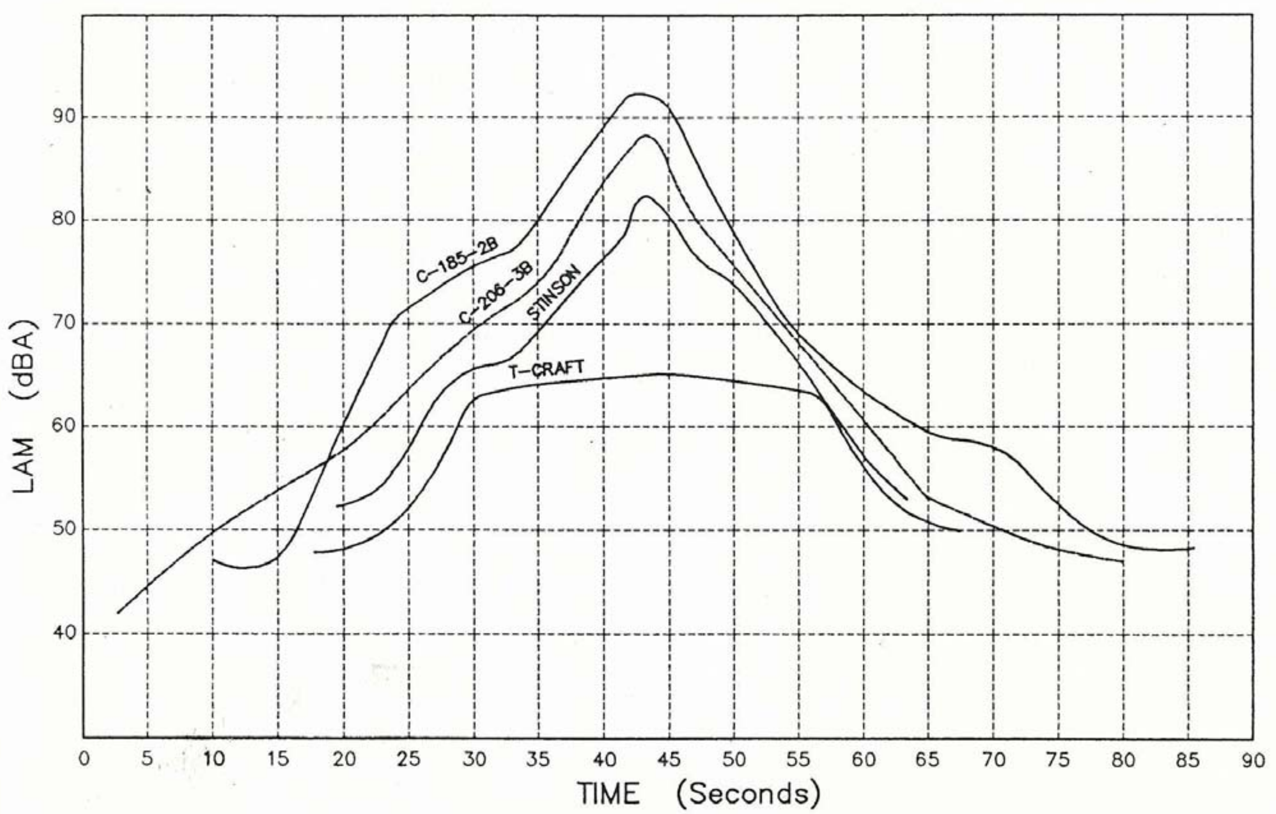


FIGURE 2: SEAPLANE TAKEOFF NOISE

3.5 Conclusion

The principal factor in the intensity of seaplane noise is first the type of seaplane (Taylorcraft 85 hp vs. Cessna 185 with 300 hp), next the tip speed of the propeller (RPM's), followed by the angle and distance that can be kept between the seaplane and the listener, and lastly the power setting (throttle). Factors, which attenuate the basic noise, produced by a given seaplane type, are in normal order of importance: reduce RPM setting, aircraft takeoff away from observer, increase horizontal and vertical distance to observer, and reduce power setting. Factors generally of much less significance and requiring empirical study for a specific site are: geographical effects of cliffs or canyons, vegetative absorption, wind strength and direction, air temperature and humidity.

4.0 <u>How Much Noise is Too Much?</u>

Now that we have a general understanding of how much noise is produced by different aircraft and how much will reach an observer, we come to the crucial question of "how much noise is reasonable?". This is a question with no black and white answer. Every seaplane base and water landing area will have its own specific conditions that must be evaluated. All of the above discussion has been about the actual noise levels that would be instantaneously measured with a noise meter during a seaplane operation. We will now consider the noise input to the community around the seaplane base -- those to whom seaplane noise is not considered music.

Table 2: Noise Level Thermometer

Level	Seaplanes	Other
110 dBA		
		* Chain Saw @ 100' (130dBA @ 3')
100 dBA		
	* C-185 Seaplane 2-blades @ 750'	* Lawnmower @ 3'
	* C-185 Seaplane 2-blades @ 1000'	
90 dBA		
	* C-206 Seaplane 3-blades @ 1000'	
	* C-180 Seaplane 2-blades @ 1000'	* Bus or Truck @ 50'
	* Stinson Seaplane @ 1000'	
80 dBA	* Seabee w/Franklin @ 1000'	
		* Bus or Motorcycle @ 100'
		* Inside pickup truck @ 60 mph
		* Neighbor's Lawnmower @ 100'
70 dBA		
		* Dishwasher on in Kitchen @ 10'
	* Taylorcraft Seaplane @ 1000'	* Heavy Rain with no Wind
		* Car @ 100'
60 dBA		* TV on in Living Room @ 10'
		* Conversation @ 5' - Inside
50 dBA		
		* Robin singing @ 50'
		* 5 mph Wind in Trees @ 50'
40 dBA		
		* Quiet House @ 5:30 AM - Inside
30 dBA		

Note: These data were all measured by the author. If adding items to this table, please relate the noise level to distance and if possible to actual horsepower and specific brand of equipment, as there is much variety in the noise output from different types of machinery. Aircraft sound levels are at full takeoff power unless noted otherwise.

Some people who object to seaplane noise just do not want to hear the seaplane at all. In addressing this issue, it is important to keep the wider context in mind. Motorboats, jet skis, chain saws, lawnmowers, motorcycles, trucks, cars, and wind in the trees all make noise. It is often helpful to take a noise meter to the site of concern and measure other noises in the background. Often, neighborhood sounds can be shown to be of a similar level to that of seaplanes. Likewise, in an urban area, the noise from commercial jets approaching and departing the local international airport often creates significant noise levels that are surprisingly high.

However, the average citizen gets used to many of these other sounds and to some extent disregards them. A seaplane take-off is a less commonly experienced or understood event. And in having this additional burden its sound can be more noticeable to a listener. Thus, it can be important to own a sound level meter and work with neighbors to educate them on the sound levels that are already existing in the neighborhood. Once they become conscious of the other sounds and that the seaplane sounds are of a similar nature to say a motorcycle at 50', their concern may diminish.

A table is provided above showing a comparison of normal community sounds, as a kind of "thermometer".

4.1 Neighborhood Compatibility

To determine the compatibility of a seaplane noise level with a surrounding community, the following factors should be considered:

1. Is the maximum sound level similar to that of other background sound levels in the neighborhood? How does it compare to train, motorcycle, truck, automobile, chain saw, motorboat, and lawnmower sounds in the vicinity? Obviously, the sound of a chain saw or motorcycle at 25 to 50 feet can easily exceed the sound level of a seaplane at 1,000 feet What are the community norms of activity?

2. What is the frequency of seaplane activity when compared to the frequency of similar noise impacts from other neighborhood activities?

3. What is the time of day for seaplane activity? A great advantage of the seaplane is that at least in the lower 48 states, seaplane activity very seldom occurs in the night hours when most people are trying to sleep.

4. What are the cumulative noise impacts from the seaplane activity when taking into account the peak noise levels, the duration of noise, the frequency of use, and the time of activity? How does this relate to the average cumulative noise in the surrounding neighborhood?

The previous discussions have focused on specific noise level readings that are measured with a noise meter during a seaplane take-off. This section of the report will now go back and define the units of measurement that are shown on the sound level meter. In addition, the mathematical descriptors and methodologies that allow for the integration and/or averaging of sound impacts from multiple flights will be presented.

The only FAA approved method of determining compatibility between aircraft noise and surrounding uses is through the use of integrated and/or averaged sound levels. These descriptors add up the sound impacts from multiple flights and consider the cumulative effect as it compares to the accumulative background noise levels in the neighborhood.

4.2 Noise Measurement

The human auditory response to sound is a complex process which varies with respect to a wide range of frequencies and intensities. In addition, people's reactions to noise differ widely. It is difficult therefore to derive a simple mathematical formula that accurately represents human reaction to noise annoyance. Decibel levels, or "dB", are a form of shorthand that compresses this broad range of intensities into a convenient numerical scale. The decibels scale is logarithmic. For example, using the decibel scale, a doubling or halving of sound energy results in a change of 3 dB; it does not double or halve the sound level dB reading as might be expected. To get into the mathematical basis for this logarithmic scale is beyond the text of this study, and the reader can find references in the library. The result of the use of the logarithm scale is that it allows the very low sound energy of rustling leaves to be compared to the enormous sound energy of a thunderstorm to be compared on a scale that goes only from 0 to 140 dB's, rather than from 0 to 1,000,000.

A change in pressure of approximately 3 dB causes the smallest change in loudness that the average human can sense. A 5 dB change is clearly perceptible, and an 8 to 10 dB change is associated with a perceived doubling or halving of loudness. For measuring ordinary sounds, a decibel level of 0 represents the faintest sound audible to the average person. Conversation level for most people is about 50 to 70 dB. Sounds become physically painful and possibly damaging above 130 dB.

4.3 Frequency of Sound

The human ear is very sensitive to sound frequencies between 500 and 6,000 Hz. Whereas a 1,000 Hz sound is audible to most people at 0 dB, a 60 Hz sound is generally not audible until it reaches a level of 40 dB.

Because a sound level meter can "hear" with equal sensitivity to sounds falling outside of the speech range, sound level meters use a weighting system to adjust the sound level reading to that approximating the human sensitivity to sound frequency. Measurements made with this weighting system are referred to as "A-weighted" and are listed in units called "dBA". Thus, the dBA is an abbreviation for the sound level in decibels determined by the A-weighting circuitry of a sound level meter. All sound level measurements should utilize the A-weighted scale, as that is the norm accepted by virtually all agencies and professionals that work in the field. It is noted that the "A" is sometimes dropped from the decibel notation in reports as a matter of convenience.

4.4 Yearly Averaged Sound Level

The federally accepted method for evaluating aircraft noise compatibility with surrounding land uses is the use of a yearly averaged sound level. The details of this methodology are contained in the FAA's Federal Aviation Regulations Part 150 Airport Noise Compatibility Planning. This can be obtained from your local FAA Airports District Office or from the Superintendent of Documents, US Government Printing Office. Part 150 defines the procedures, standards, and methodology for the creation of airport noise exposure maps and airport noise compatibility planning. It prescribes a single system for "measuring noise at airports and surrounding areas that generally provides a highly reliable relationship between projected noise exposure and surveyed reaction of people to noise." It provides a single system for predicting the exposure of individuals to noise from the planned operations at a future airport. Part 150 also identifies land uses that are normally compatible with various levels of noise exposure. The document is intended to provide the framework for airport operators in conjunction with local, state, and federal authorities, to create noise compatibility planning and implementation programs.

Part 150 is also the basis of a federally funded program to promote noise compatibility between airports and surrounding communities. The definitions within Part 150 limit the availability of federal funding to public use airports, including "any airport which is used or to be used for public purposes, under the control of a public agency, the landing area of which is publicly owned". This definition would apply to many seaplane bases and water landing areas as many are located on navigable waterways that are controlled and owned by public agencies.

Some state aeronautics divisions have developed state standards for airports that parallel the FAA's standards. The seaplane pilot is encouraged to research their own state regulations to determine if there are mandated requirements relative to utilizing the Part 150 methodology.

In summary, the methodology of Part 150 is to create a "noise exposure map" which shows a scaled depiction of the airport, with noise contours showing the intensity of averaged aircraft noise impact on the surrounding area. Each contour shows the "day-night average sound level" (Ldn) around the airport. The contour of most significance is the 65 dBA average sound level. To go further we will need some definitions:

- Maximum sound level (L_{AM} or L_{MAX}) is the maximum A-weighted, slow response sound level recorded during a single event (e.g., take-off) during a given time interval. It provides information that is used to calculate the L_{AE} and the Ldn.

- Sound exposure level (L_{AE}), also called a single event level or SEL, is the sum of all of the sound energy within a single event (e.g., take-off), which is presented as an equivalent intensity of 1 second duration. From a computational standpoint, when the noise environment is caused by a number of different identifiable noise events such as takeoffs or fly-over's by differing aircraft, the L_{AE} provides a convenient calculation method for determining the combined impact as a single Ldn. The L_{AE} is what a noise meter would read if you compacted the whole seaplane takeoff sound energy into a 1 second operation.

- Yearly "Day-night average sound level" (Ldn) means the annual average sound level in decibels, after the addition of 10 dBA to sound levels for the periods between 10 PM and 7 AM. Even though the Ldn is usually computed as a 24-hour average, it is called a "yearly" day-night average sound level because it is intended to be the average of all activity throughout the year.

- "Average sound level" (Leq) means the level, in decibels, of the mean-square, A-weighted sound pressure during a specified period. If there are no activities between 10 PM and 7 AM, the Leq is equal to the Ldn.

4.5 Sample Calculation

As an example computation of an Ldn we will use the following example:

Aircraft:	Cessna 185, 2-bladed prop
Water Lane Location:	1,000 feet distant from observer
Number of Operations:	1 take-off per day (365 per year)

The first step is to take the noise readings shown in Figure 3 above, and add up all of the sound energy under the curve and normalize it to 1 second. Figure 5 below shows this in a graphical form. Because of the logarithmic nature of decibels, it is not a strict measure of the area under the curve. The reader will have to refer to technical books for a mathematical description of this conversion. Some sound level meters are able to read out this value directly, which makes this step easier to perform.

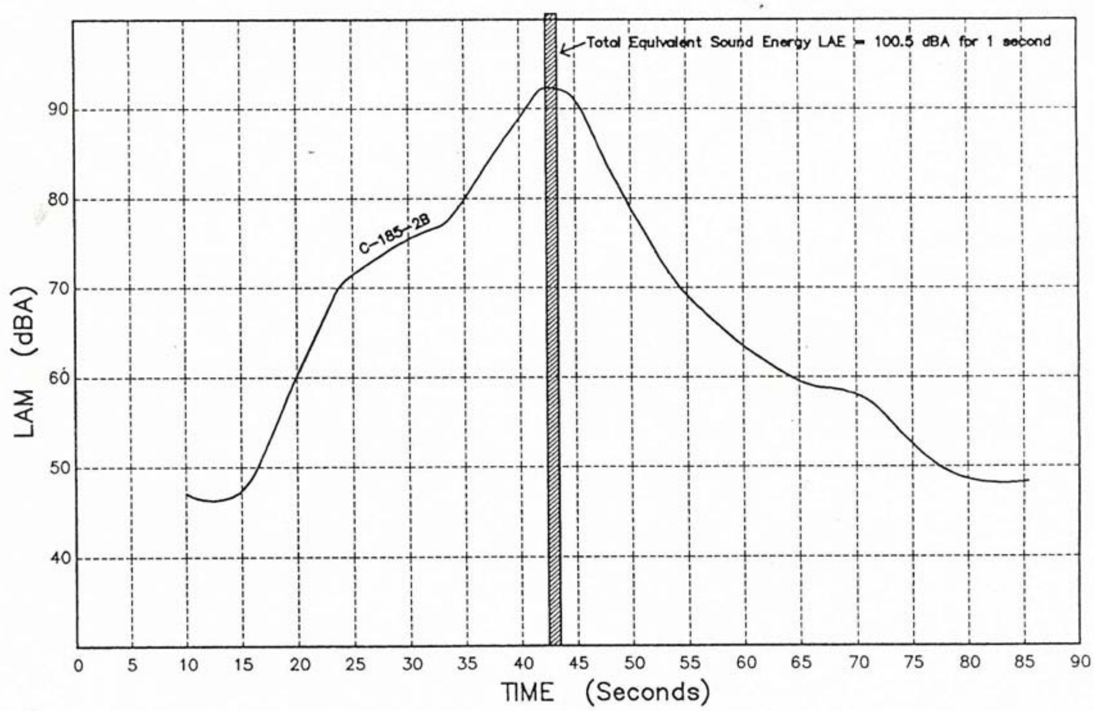


FIGURE 3: INTEGRATED SEAPLANE TAKEOFF NOISE

The computation of the Ldn then involves adding the sound energy from the total annual number of these events together (each of which were normalized to 1 second) and then to divide that sum by the number of seconds in a day, which is 86,400 and the number of days in a year, which is 365. The Ldn for our sample case of one Cessna 185 flight per day at a distance of 1,000 feet utilizes the following formula:

$$Ldn = 10 \log \left[\frac{N \times 10^{LAE/10}}{86{,}400 \times 365} \right]$$

where N = 365 flights per year, and LAE = 100.5 dBA

$$Ldn = 10 \log \left[\frac{365 \times 10^{100.5/10}}{86{,}400 \times 365} \right]$$

$$Ldn = 51.1 \text{ dBA}$$

Thus, the Ldn at 1,000 feet from a Cessna 185 doing one takeoff a day is a low number. This is because in spite of the annoyance it might give to someone, it is not really producing a large amount of sound. The typical background noise level in most urban areas is in the range of 55 to 65 dBA, with the dense downtown urban core areas being in the range of 65 dBA to 75 dBA. The average background noise in a rural area is typically in the range of 45 to 55 dBA. The 51 Ldn computed above shows that the sound energy from the floatplane of this example on average is not a significant factor in the noise environment of both urban and rural waterways. One could measure the noise impact from motorboats, cars, trucks, motorcycles, chain saws, lawnmowers, and so forth and find that their noise contribution to the environment exceeded that of the floatplane.

One additional formula that may be useful to the pilot is a typical relationship between L_{AE} and L_{AM} as used by the FAA in their Integrated Noise Model:

$$L_{AE} = L_{AM} + 7.19 + 7.73 \log (D/1000)$$

where D is the distance in feet.

Thus, for the C-185 shown in Figure 2 above, where L_{AM} = 92 dBA and D = 1000 feet, we can compute:

$$L_{AE} = 92 + 7.19 + 7.73 \log (1000/1000)$$

$$= 99.92 \text{ dBA}$$

This is close to the 100.5 dBA computed by the sound meter during the actual noise test and shown in Figure 5 above. It should be noted that this formula is only useful for aircraft while in motion (i.e., not for steady state sounds such as an extended aircraft run-up).

4.6 FAA Part 150 Noise Compatibility

The FAA's Part 150 document includes a table identifying land use compatibility with the Ldn. The table contained in Part 150 is essentially the same table contained in "Guidelines for Considering Noise in Land Use Planning and Control", a federal interagency document adopted by the US EPA, US DOT, US HUD, US DOD, and the Veterans Administration. It indicates that all of these agencies agreed that all land uses are compatible with an Ldn that is below 65. For Ldn impacts greater than 65 there are recommendations that compatibility is questionable, but that it might be achieved if residential or school use buildings are designed to achieve noise level reductions over and above that achieved through normal residential construction.

Further analysis of the example computation in Section 4.4 for a Cessna 185 taking off once a day indicates that the Ldn of 65 dBA isn't reached until being within approximately 200 feet of the takeoff path. For a Taylorcraft the Ldn of 65 dBA is located only 50 feet from a daily takeoff path.

The normal method of computing the Ldn noise contours is through the use of an FAA computer program called the Integrated Noise Model (INM). The INM allows input of multiple runway locations, use of multiple types of aircraft, use of multiple approach and departure profiles, with various differing power settings, and allows input of varying take-off distances and speeds.

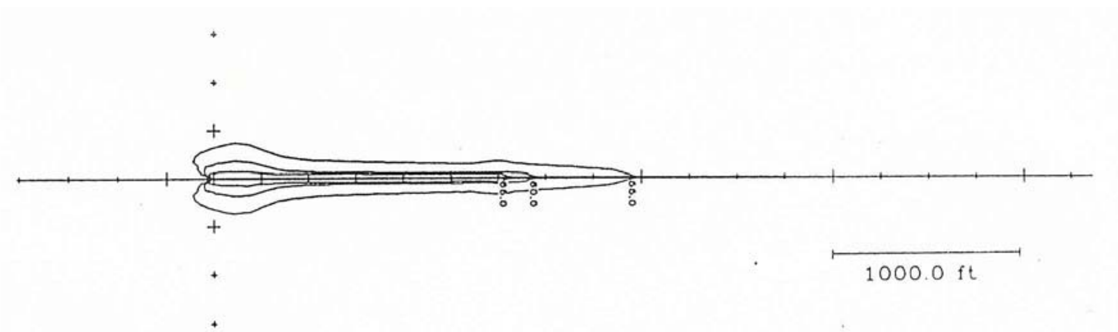
The actual creation of a noise exposure map should be created by use of the INM utilizing a detailed input of data that defines the actual seaplane L_{AE} noise levels vs. distance, approach and departure profiles, power settings, take-off distances, and flight paths. Utilizing the INM with data that corresponds to the aircraft shown in Figure 2, several noise exposure maps showing the 65 Ldn contour are shown below for various amounts of flight activity.

Since the sound exposure of one Cessna 185 with two-bladed prop is the same as three Cessna 185's with 3-bladed prop, nine Stinsons, or 125 Taylorcrafts, the contours represent different numbers of flights depending on the noise output of the aircraft.

Figure 4: Taylorcraft 85 hp Seaplane -- 52 flights/year

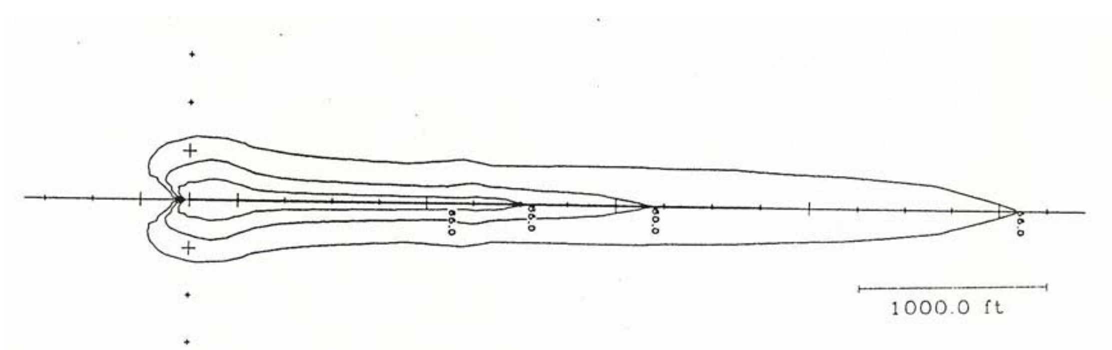
Ldn Contours: 55, 60, and 65 dBA

Figure 5: Stinson 250 hp Seaplane -- 52 flights/year
(or Taylorcraft 85 hp Seaplane -- 722 flights/year)



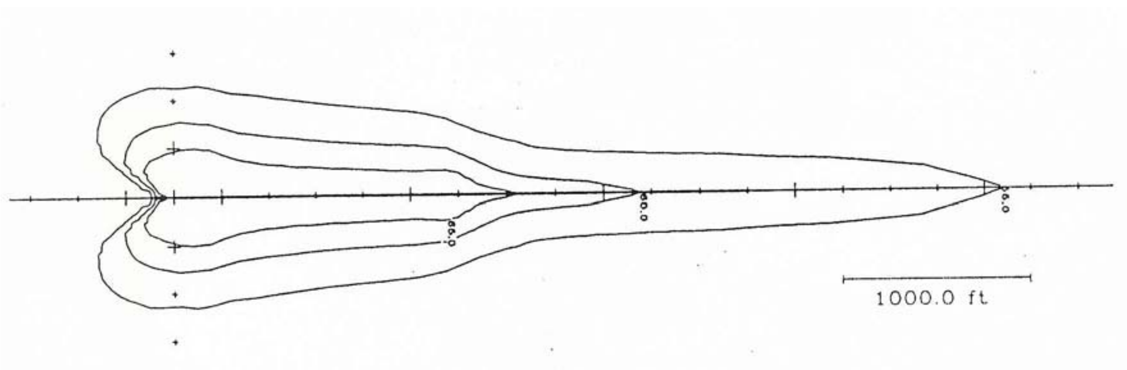
Ldn Contours: 55, 60, and 65 dBA

Figure 6: Cessna 206 300 hp 3-blade propeller -- 52 flights/year
(or Stinson 250 hp Seaplane -- 156 flights/year)
(or Taylorcraft 85 hp Seaplane -- 2,166 flights/year)



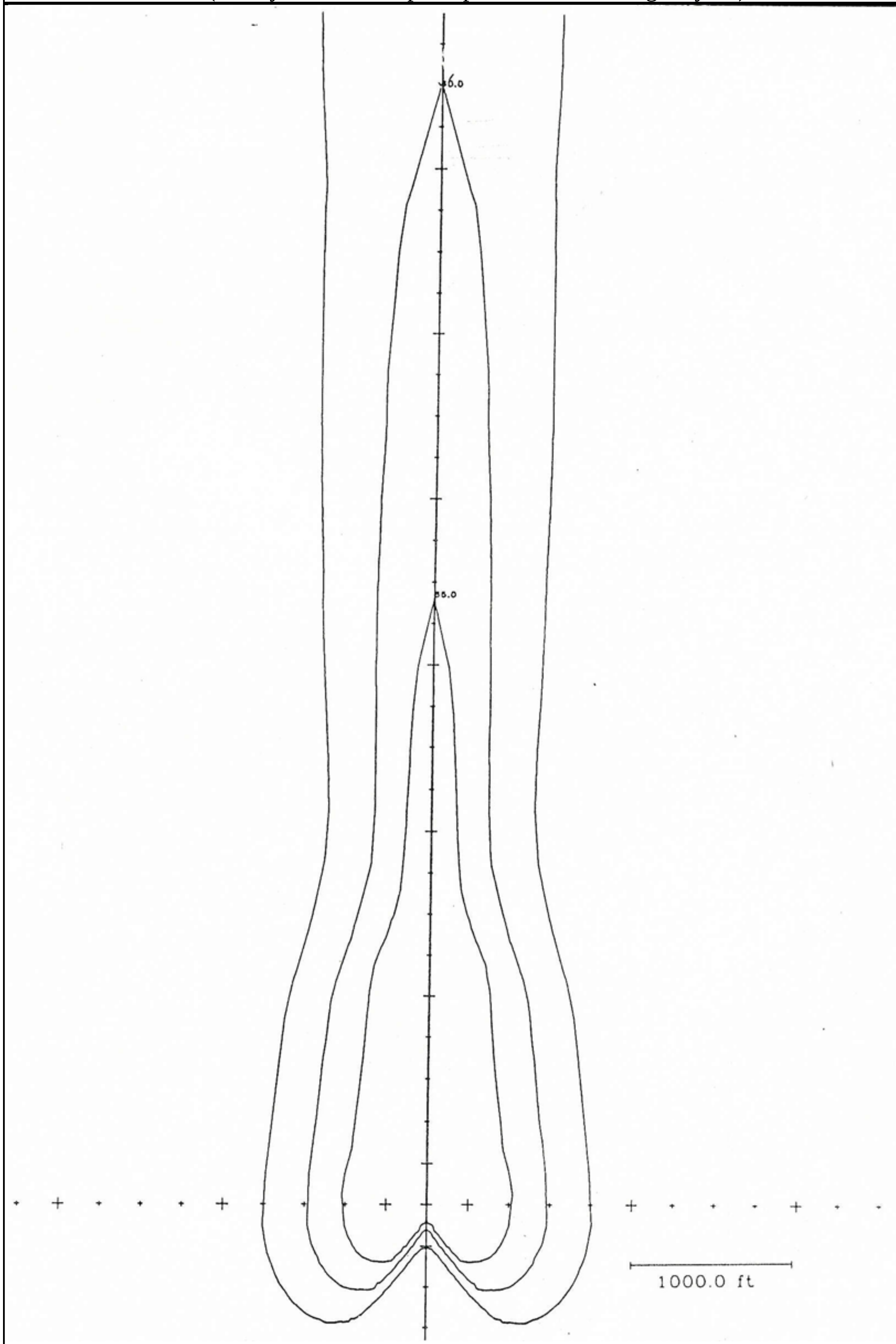
Ldn Contours: 55, 60, and 65 dBA

Figure 7: Cessna 185 300 hp 2-bladed propeller -- 52 flights/year
(or Cessna 206 300 hp 3-blade propeller -- 156 flights/year)
(or Stinson 250 hp Seaplane -- 468 flights/year)
(or Taylorcraft 85 hp Seaplane -- 6,500 flights/year)



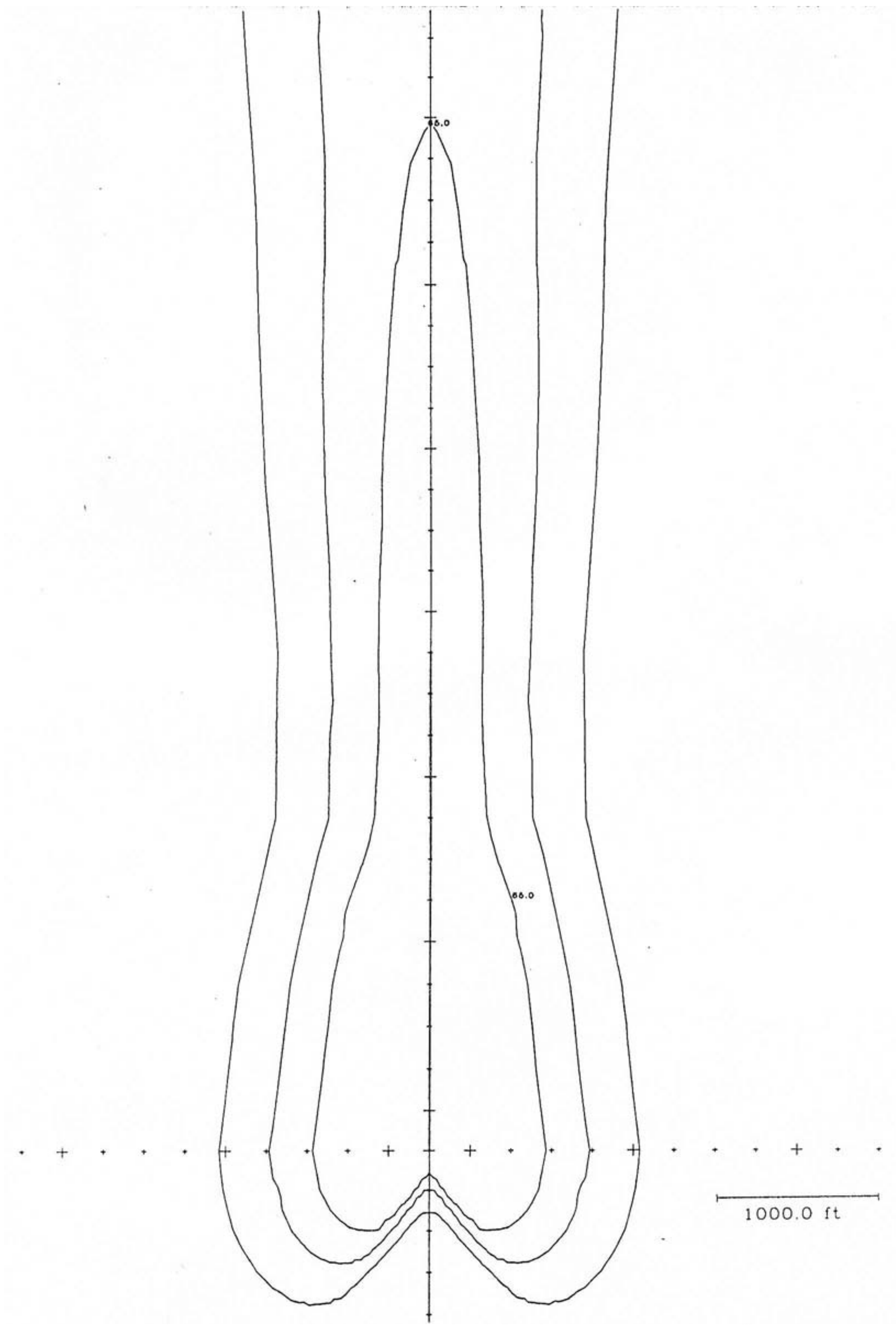
Ldn Contours: 55, 60, and 65 dBA

Figure 8: Cessna 185 300 hp 2-bladed propeller -- 365 flights/year
(or Cessna 206 300 hp 3-blade propeller -- 1,095 flights/year)
(or Stinson 250 hp Seaplane -- 3,285 flights/year)
(or Taylorcraft 85 hp Seaplane -- 45,625 flights/year)



Ldn Contours: 55, 60, and 65 dBA

Figure 9: Cessna 185 300 hp 2-bladed propeller -- 1,000 flights/year
(or Cessna 206 300 hp 3-blade propeller -- 3,000 flights/year)
(or Stinson 250 hp Seaplane -- 9,000 flights/year)
(or Taylorcraft 85 hp Seaplane -- 125,000 flights/year)



Ldn Contours: 55, 60, and 65 dBA

The point of spending the time to go through this much detail is to show that under the FAA's standard methodologies for determining compatibility between airports and surrounding communities, small or modest amounts of seaplane activity will generally be found to be compatible. Even though the seaplane may be clearly audible, the total amount of sound energy will generally be low and not greatly different from that of other sounds occurring in the waterway.

The sound of an airplane may be more annoying to some people than that of a motorcycle or jet ski or chain saw, but as pilots and seaplane base operators we must keep bringing the noise issue back to the fact that the total amount of sound energy from seaplanes is generally very small when compared to other environmental sounds in a neighborhood.

In conclusion, it is clear that there is no set distance that will make a seaplane sound compatible with a community. With smaller seaplanes, it is clear that the sound levels are essentially equivalent to that of a powerboat or other common activity in the community.

4.7 Other Airport Noise Metrics

The Ldn is our federal government's only currently accepted airport-community compatibility noise metric. However some states (or other countries) have adopted slightly different noise metrics. Other metrics include:

- Noise Exposure Forecast (NEF): A descriptor developed in 1967 based on EPNdB as the unit of aircraft noise. Operations during the period 10 PM to 7 AM are weighted by a factor of 16.7 per one operation.

- Time Above a Specified Threshold (TA): The time in minutes that a dBA level is exceeded during a 24-hour period.

- Community Noise Equivalent Level (CNEL): Primarily used in California; is similar to Ldn, however it incorporates a 3 dBA penalty between the evening hours of 7 PM and 10 PM, in addition to the 10 dBA penalty between 10 PM and 7 AM.

- Weighted Equivalent Continuous Perceived Noise Level (WECPNL): Is primarily used by the European Community; based on the PNLT metric with a 3 dBA penalty between 7 PM and 10 PM, and a 10 dBA penalty between 10 PM and 7 AM.

- Equivalent Sound Level During Daytime Hours (LEQDAY): An energy summation of the aggregate environment, normalized to the 15-hours between 7 AM and 10 PM.

- Equivalent Sound Level During Nighttime Hours (LEQNIGHT): An energy summation of the aggregate environment, normalized to the 9-hours between 10 PM and 7 AM.

The current FAA standards listed in Part 150 do not utilize any of these other airport noise metrics. Unless your state has adopted one of these standards, no use should be made of them. If your state requires any of these metrics, the FAA's Integrated Noise Model is able to predict them.

4.8 FAA Certificated Aircraft Noise Levels

FAA regulations have established "Certificated Noise Levels" for aircraft. Prior to December 22, 1988, the standards were called "Appendix F" and required determination of the maximum noise level of an aircraft flying at cruise speed in cruise configuration at maximum continuous power settings (not "take-off" power and propeller settings) at an altitude of 1,000 feet. Thus, it provided a measure of common cruise noise levels during overflight of an area.

After December 22, 1988, the noise standards were revised to those of "Appendix G". This newer measurement system requires measurement of the maximum noise level directly underneath the aircraft track, 8,200 feet from the start of the take-off roll, with flight conducted at the speed for best rate of climb Vy. With power and RPM settings at maximum continuous levels allowed per the Pilot Operating Handbook. Thus under Appendix G the noise measurement is not at a fixed distance, and rewards the climb characteristics of an airplane with a lower certificated number.

Thus, because of the way it is determined, the FAA certificated noise level is a number that is generally not appropriate for studying takeoff noise impacts.

4.9 Noise Level Descriptors not Used for Aviation

There are some noise level descriptors used in other contexts which it may be advisable for the pilot to be aware of. They are mentioned here only so that the pilot can be aware that differing standards may exist for other purposes, and they are generally to be avoided. An example of a different noise descriptor is the Federal Highway Administration's Hourly Equivalent Noise Level ($Leq_{(Hourly)}$) and L_{10}(Hourly) which represents the sound level which is exceeded 10% of the time. These descriptors are used for highway noise analysis but should not be applied to aviation.

The Occupational Safety and Health Administration (OSHA) has set federal standards at which noise is considered a health problem and actual hearing loss may occur. In summary, OSHA standards are that all noise should be less than 140 dBA and that averaged noise levels (Leq-OSHA, computed slightly differently from Leq) must be below a value which varies according to duration. For example, over an 8 hour period the Leq-OSHA must be less than 90 dBA, whereas for 15 minutes or less the Leq-OSHA must be less than 115 dBA. It is clear that although this standard does not apply to aircraft, seaplanes will easily comply with this standard.

Most local zoning ordinances include a maximum allowable noise level. Typically a zoning ordinance table is read in units of L_{AM}. The table often shows a land use zone of the noise source (such as industrial, commercial, or residential) and then a land use zone of the receiving property (industrial, commercial, and residential). The table is in the form of a matrix and often includes exceptions for shorter or longer duration sounds. These tables usually except motor vehicles and noises governed by federal law or standard.

If a local agency tries to make a seaplane comply with this kind of L_{AM} table, the pilot may have a difficult time, since most motorcycles, cars, trucks, trains, chain saws, lawnmowers, barking dogs, crowing roosters, car alarms, house alarms, and other aircraft flying overhead will typically violate the standards listed in this kind of table. It is important for the pilot to carefully evaluate such information, as it should not be applicable to seaplanes due to federal preemption and the existence of FAA standards which already apply.

4.10 Taking Noise Measurements

Pilots are encouraged to buy a noise level meter (one is available from Radio Shack for a very low price). Seaplane noise abatement procedures are necessary to maintain a "fly neighborly" relationship to others living along and using our nation's waterways. Since it all comes down to personal pilot knowledge, all seaplane pilots would be wise to get together a group of friends and share the cost of an inexpensive noise meter. Measure each other's takeoff's and fly-over's and see how little sound you can make!

While taking your measurements make sure that you're not recording the voices of others nearby, it requires complete silence near the meter microphone or the readings will be no good. If a group of pilots got very interested, they could invest in a recording sound level meter which has a computer chip in it that samples and records the noise level at intervals. This allows a print-out of the data and the computer chip can also create the L_{AE} and the Leq (same as Ldn during daytime) values directly from the meter. There are several good meters for this purpose; the author uses a Larson-Davis 720.

Owning a sound level meter can have a good side benefit. With it the pilot can show neighbors, planning department officials, and other interested parties that the noise level from other vehicles and community activities often are the same or greater than that of seaplanes.

It is important to note that most videotapes and audio tape recorders have automatic volume control circuits within them, and thus they do not provide an accurate record of sound levels. However, if you are using a recording sound level meter it is helpful to have an audio recording of the same event (the author uses a Dictaphone) in order to be able to go back and identify the beginning and end of events as well as other noises which impinge on the noise measurements (such as a noisy boat or a neighbor's lawnmower). Also, a sound level meter microphone must be shielded from the wind, as the meter can record the sound of the wind in the microphone if the observer is not careful.

It is best to repeat noise tests several times if extreme accuracy is required. Values within 3 dBA are generally considered acceptable, since the human ear can generally not distinguish differences of 3 dBA or less.

Some have claimed that water can cause a lens effect and focus sound, or that rough water can absorb noise. This author is not aware of any data that supports those concepts, but would look forward to seeing supporting data if it exists. Certainly when water is rough there is a lot of wind which with breaking waves on a shoreline would create a high background noise level, which would mask seaplane sounds.

5.0 <u>Seaplane Noise Abatement</u>

5.1 Take-off Noise

During take-off there are three issues with the pilot can take into account:

- o Direction of take-off,
- o RPM settings, and
- o Flight path.

A take-off directly away from a noise sensitive use will result in a great attenuation of sound as shown in Figure 2 above. It will also have the benefit of increasing distance, which continuously reduces sound level. However, direction of wind and waves will often generally have to take precedence.

Once off the water (or right from the start, if possible) the pilot can consider reducing RPM's. This will make a substantial decrease in sound impact, especially with the medium and larger size seaplanes.

Finally, given that the takeoff will be into the wind, once the seaplane is airborne it is desirable to alter the direction of flight to maximize the slant distance between noise sensitive uses and the seaplane. It is noted that where water surface area is small, the RPM setting is probably more effective in reducing impact to a residential area than rapidly gaining altitude. Using the information contained in this report, the pilot can make a determination on this issue for their specific case. Ultimately it may take the use of a noise meter and discussion with neighbors to determine the procedures most beneficial to the community.

5.2 Fly-over Noise

Normal seaplane landing procedure is to fly over the water landing site at an altitude of 500 feet AGL on downwind for a final look at wind direction, water debris, boats, other traffic, wave conditions, and docking considerations. The 500 feet AGL is used in lieu of the standard 1,000 feet AGL at a land airport in order to promote better observation and visibility. In fact, if the pilot feels uncertain about landing conditions, the pilot will make a low pass over the water landing area as further reconnaissance prior to landing.

Low flight at high RPM settings can be a substantial noise problem to a community. Figures 8 and 9 show that noise contours can continue well beyond the water landing site if large amounts of traffic use maintain takeoff power throughout the departure. Sound spreads spherically around the plane and the seaplane's impact at 500 feet above an observer is not substantially different from what it would be 500 feet horizontally from an observer. In fact, it may be slightly more in the vertical direction because there is no chance of ground absorption of any type. The vertical dimension is further aggravated by the fact that water obviously sits at the lowest elevation whereas the land rises around the sides. 500 feet AWL (above water level) may only be 200 feet AGL where there are hills beside the waterway. In some river sites, within a short horizontal distance, the terrain may rise 300 feet (or more). Obviously in such a location 500 feet AWL equals only 200 feet AGL for the neighbors under the flight path. This could result in a noise impact of 5 to 7 dBA increase over that of the intended 500 feet fly-over.

5.3 Minimizing Noise

Obviously it is necessary to do proper reconnaissance of a water landing site, the key is to plan your flight so that you are maximizing your slant distance (shortest distance on the diagonal) between you and noise sensitive uses such as houses. Thus, pick your downwind flight path to take into account both horizontal and vertical separation and maximize the actual distance between the seaplane and a house or group of people. The second and equally important mitigation is to perform all low altitude fly-over's at the minimum RPM settings consistent with safe flight.

It is recognized that this puts some extra burden on the pilot, to add in these considerations during the landing phase of flight, which already has a high level of complexity. The fundamental rule for noise abatement procedures is: "Safety comes first." In other words, perform as much noise abatement as you are comfortable with, but control of the aircraft and maintaining safe flight conditions always comes first. For locations where regular visits occur by pilots not familiar with the landing area, a simple diagram can be created and circulated among local seaplane pilots, to encourage the use of noise abatement procedures. Many commercial seaplane bases do this. There is no reason that even a personal seaplane base operator could not do this. The neighbors to the water landing site will undoubtedly be less annoyed than otherwise, and the seaplane operator will have less difficulty keeping his seaplane base open.

If you are able to double the slant distance between your seaplane and a noise sensitive land use, you have reduced the sound energy received to one-fourth its previous level, and the sound level meter will read approximately 5 to 6 dBA less. Backing off the propeller RPM's by 10% can for many aircraft reduce the sound level by 5 to 10 dBA. Likewise, to reduce your power setting to 50% power will reduce the sound level another 5 dBA. These kinds of reductions are very helpful.

As seaplane pilots we must constantly work to perform our flight operations in the most responsible method possible, so that what conflicts do occur between seaplane operations and surrounding communities are issues that are essential and not just problems caused by a lack of use of simple noise abatement procedures.

Finally, to deal with the actual takeoff and landing noises while on the water, one can take off or land away from the intended tie-down position and then taxi the final distance. This will be useful when there are large bodies of water available. However, the bigger issue will generally be the fly-over and departure flight paths and the power settings associated with each of these phases of flight.

If the issue of noise impact relates to a need for quiet inside of a building, there are building construction methodologies which can be used to attenuate seaplane noise. Insulation can be added to walls, an air conditioner can allow windows to be kept closed, and storm windows can be added to attenuate sound coming through windows. These kinds of building improvements are common around major airports as a method of making commercial jet traffic more compatible with surrounding residential areas. A well constructed house with windows closed will generally provide a noise reduction of 25 to 35 dBA's from that outside the building. If the windows are opened, the noise reduction may only be in the range of 10 to 25 dBA.

6.0 How to Deal with a Complaint

If and when a seaplane pilot hears that there is a complaint, the first thing to do is be thankful that you know there is a problem to be dealt with. In such situations it is natural for the pilot to feel defensive or concerned that his operation is in jeopardy, but the pilot will be better served to assume that there is a problem to be solved and take on a "can do" attitude. It is recommended that the following approach be taken:

- Ask to meet with the person making the complaint. Try to meet at their house and spend an initial period just listening. Draw the person out as to the specifics of the problem, how often it has occurred, what it sounds like, can they see the plane, and so forth. The more information you have the better you will be able to understand the problem.

- Your initial response to their comments would best be to repeat back to them a summary of their concerns to make sure that you have heard them correctly, and to let them know you heard them. After repeating back to them their concerns, they may be receptive to a short description by you of why you thought your operations would not have bothered them. But following a very brief discussion of that subject, it is wisest to suggest that you would like to consider their concerns for a day and then come back and talk further.

- This allows you time to consider your standard flight paths, power settings, and so forth and to do some estimating of the likely noise impact you may be creating at their property. Out of this consideration you may conclude that there are changes to your operation which can be done to reduce the noise to them, or you may conclude that you think the noise impact to them is actually very minor.

- At a return meeting with them a day later, you can then review your thoughts with them. You could then invite them to come down and see the seaplane and if they are willing, offer a ride to show them what your options are for flight paths.

- If possible, it is very desirable to have another pilot fly your standard flight path while you are at your neighbor's house listening to the noise and watching the plane. Preferably you would have a recording noise meter available so that you can have a precise record of what the actual noise is. If there are alternative flight paths to be considered, it is desirable to have the other pilot fly them while you and the neighbor observe the differences. This way both the neighbor and you, the pilot, get the benefit of hearing the outcome of different options.

- Finally, it all comes down to the issue of human relationships, so you have to try to work out the best arrangement you can with your neighbors. Perhaps there are certain times of day where flight can be avoided, or perhaps there is a preferred alternative flight path when wind conditions allow.

- It is highly desirable to call back a month or two later to see if the problem still exists at the same level it initially did. Hopefully it doesn't, but if it does, you the pilot may as well know the truth of the situation.

The approach described above is one that attempts to promote communication between parties. If the communication falls apart, then there is more likelihood that the person complaining will go to the FAA, or local noise, planning, or land use authorities and try to get others involved in evaluating your seaplane operation. This will result in more complication.

Thus, it will generally be in your best interest to try to find a resolution with your neighbor that works. If you have tried to work the situation out with the neighbor before they go to local authorities, you are in a much stronger position, since you showed an effort in trying to work with the neighbor. As the pilot, you want to be the good guy to the extent that you possibly can.

7.0 Conclusion

As an airplane pilot, you are primarily regulated by the FAA. Due to the concerns for protecting interstate commerce, the FAA will generally claim federal preemption as concerns all issues concerning flight, including noise. However, the FAA generally does not take an advocacy position for land use decisions concerning the establishment of new airports. The compatibility of a new airport with a surrounding land use is generally left to local agencies such as planning commissions, city councils, and state government.

If you are required to perform noise testing and analysis for establishment of a new seaplane base, you will most likely have to go through an extensive land use process with your local governing agency. From a noise standpoint, you should try to utilize the existing FAA noise compatibility guidelines which are contained in Part 150 and in the five agency "Guidelines" (see Section 4.5 above). By the use of those FAA standards it is generally possible to show that a modest amount of seaplane activity will be compatible with nearby residential land uses.

However if the local land use agency tries to make you comply with a different sound level standard, your approval may be harder to achieve, especially with larger size seaplanes. Many local ordinances have an exemption for activities that are governed by federal standards. If this is available, then you should use this exemption to bring the FAA standards into applicability.

Alternatively, you may need to determine whether the local noise standard (such as a maximum noise level) would prohibit the use of chain saws, motorcycles, cars, trucks, and alarms in any neighborhood. Then you must appeal to a sense of fairness and equality under the law.

The good news is that when compared to the typical airport noise problems at our major urban centers, seaplanes are a relatively minor consideration. If the seaplane is small, and the number of operations is small, it can be completely compatible with any waterway as its noise level will be similar to that of outboard motors, jet skis and other common waterway sounds. Medium sized seaplanes such as Cessna 185 and 206 can be compatible with a relatively small area as long as the number of operations are small and the immediate noise impact is kept to a minimum through reduced RPM's and other measures.