Attenuation of Point Source Airborne Cultural Noise

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Introduction

Successful separation of 'noise' from signal depends on the ability to characterise the noise signature and to differentiate it from the desired signal. Here we present data that has been contaminated by cultural noise at a producing SAGD plant during a time lapse monitoring project. We attempt to understand the noise characteristics such that we can recreate them and subtract them from noise affected data. The cultural noise studied here is primarily transmitted through air from a relatively small source point, such as a gas flare, over a range of frequencies many of which are audible. These types of noise are increasingly of concern in time lapse monitoring because much future time lapse monitoring work will take place in close proximity to production facilities, economic considerations preclude shutting down such operations in support of geophysical investigations. Cultural noise considerations will be crucial. Many production based facilities produce noise over the typical seismic bandwidth, some examples of noise producing sources are flarestacks, pipelines, compressors, boilers and pumps. Each will have a characterstic signature, some are more easily attenuated than others. For example, pipelines produce dispersive surface waves that are difficult to deal with. In this communication we discuss simple airborne noise that travels directly from the source to the receiver relatively undispersed. A typical example of a contaminated shot gather from such a site displays higher frequency airborne sound with 'hyperbolic' moveout centred at Channel 110. This noise interferes with the strong ~750 ms reflector from the top of the Paleozoic carbonates. Dispersive buried pipeline noise appears at the left side of the image. Here we discuss the use of mean and median filtering methods, the end points of the well known alpha-trim filter, in an attempt to reduce the interference caused by the airborne cultural noise.

The mean and median filters are commonly aplied to seismic data to enhance coherent signal. For example, a median filter is often used to determine the local input pulse for removal in upgoing-downgoing wavefield separation. Here we present the use of these filters to remove unwanted signal or noise. Capitalising on the coherent moveout of the noise signal. it may be transformed such that it is seen as coherent flatlying events. Mean and median values for differing filter widths are subsequently subtracted from the unfiltered data to produce a cleaner data set as is shown in both pre-stack and post-stack results.
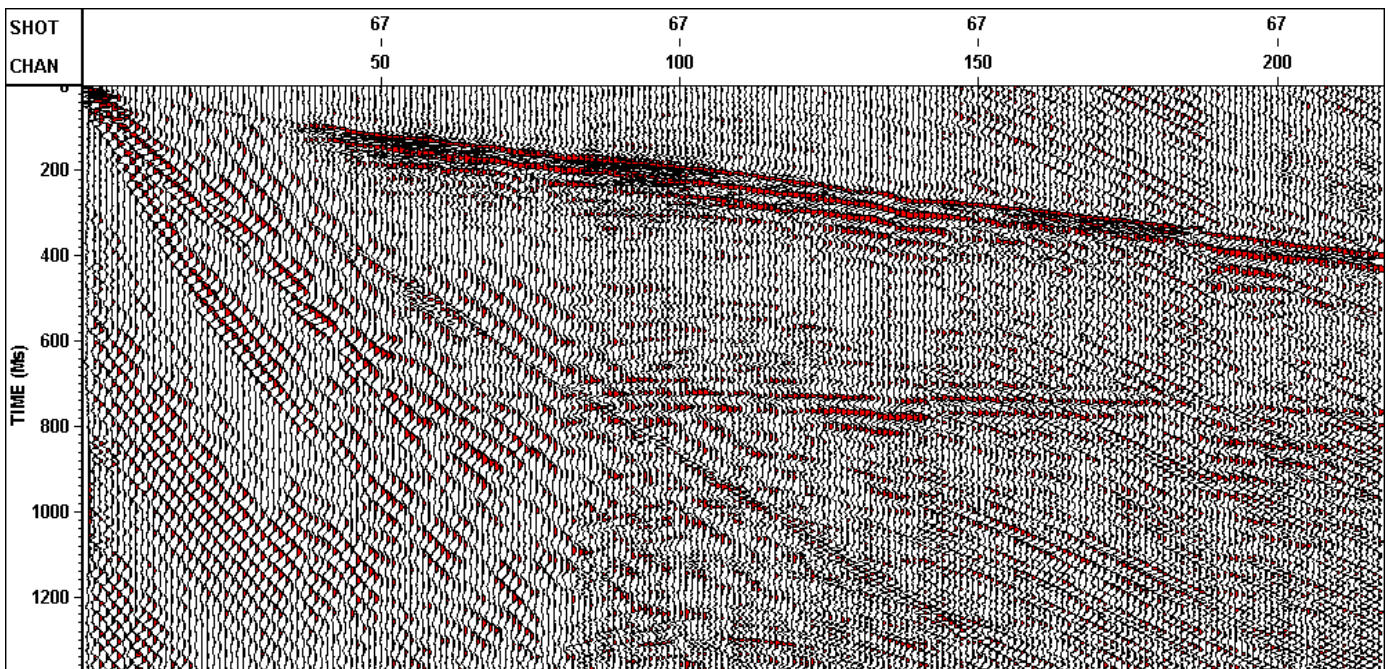

Figure 1) Single shot gather showing the background noise. Data obtained from stacked mini-vibrator 12-150 Hz sweeps acquired using a 240-channel system with 14-Hz geophone singles spaced at 3-m.

Noise Characterization

To succesfully separate signals one must first understand the nature of the signal and noise. For example, coherent noise must be handled signfiantly differently than random noise. The coherent noise found on the shot gather is prominent through out the whole record but can be deemed as background noise. The data shown are from a timelapse survey over a SAGD site where the cultural

noise produced by the operating plants can be very detrimental to data collection. Care was taken to deploy geophones such that good coupling is attained and also to cover them with dirt to reduce effects of audible noise or rain. Data was carefully monitored during recording to eliminate avoidable disruptions but a quiet period at the plant was never observed. Passive listening with the array was also recorded to aid in characterisation. The passive traces(Figure 2a) clearly show the noisy signal following a regular moveout. Amplitudes are highest nearest to the source and decay to the sides. Though amplitudes naturally attenuate by spherical spreading the variations in ampliutude are more complex but are consistent with the field layout where the far ends of the line lie behind hills while the centre is exposed directly to the plant. Aside from the moveout there appears to be very little that is coherent about the data. Neither the amplitudes nor the frequency are consistently stable . Assuming that the noise is audible, and most likely a flare, a model of the moveout is calculated using a source distance of 140 metres and a propagation velocity of 343 m/s. This compares very well with the time picks of an event. (Figure 2b)
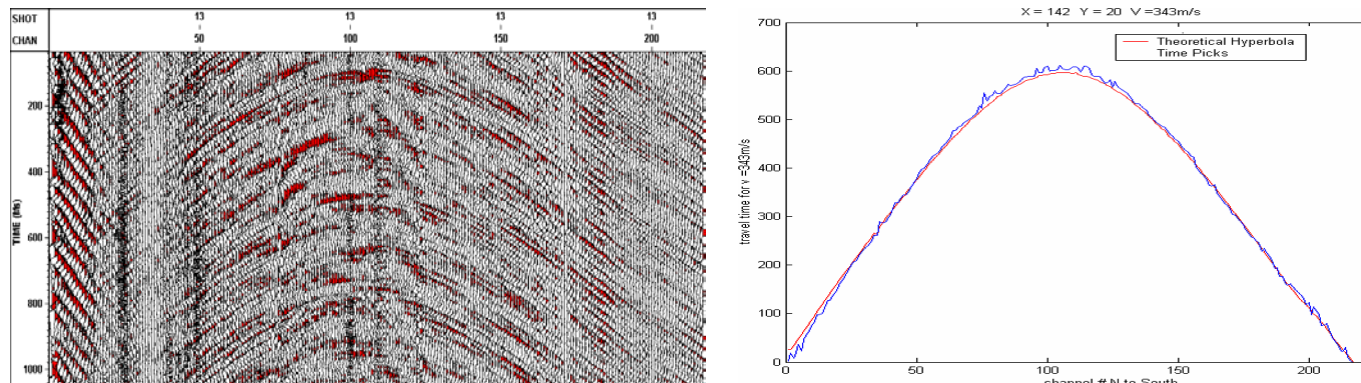

Figure 2a) Passive data collected at the site showing just the noise signal and its coherent moveout pattern. Also visible is noise believed to be due to a pipeline at the South (left) end of the line. Figure 2b) Picked moveout (blue) and calculated moveout (red) for an audible noise source at a horizontal distance of 142m (x) and a vertical height of 20m (y) calculated using v=343m/s

Methodology

Once the data has been flattened along the calculated moveout the noise signal appears as flat lying events while reflections become smiles. In effect, the noise is laterally coherent locally while the desired information becomes incoherent. The mean or median filter can be applied to recreate the noise for subtraction from raw data. The noise is separated by representing it in each trace as either the median or mean value of a given number of traces to each side. Subtraction of the noise estimate from the raw shot gather gives a noise reduced filtered shot gather. Care must be taken at the top of the moveout curve due to the fact that the curve approaches horizontal there and, hence, is not distinguishable from desired signal. The top of the moveout occurs close to the centre of the shot spread which is advantageous given the high stacking fold at the centre of the line. Wider filter widths were attempted along the top but in the end the most effective method was to not filter between traces 90 and 120. This does not effect the final stacked sections much as the fold is high enough to reduce the noise through later stacking for construction of the final seismic image

To illustrate the effectiveness of this method we first present its application to the passive noise data (Figure 2b). After flattening of the the noise (Figure 3a.) is more laterally coherent. Subtraction of the 9 Pt. Median filter and then remapping the data to the original x-t reference frame produces the noise reduced shot gather. (Figure 3b.) After noise subtraction the dispersivie pipeline noise is still visible on the south end (left) of the line while the rest is just random noise.
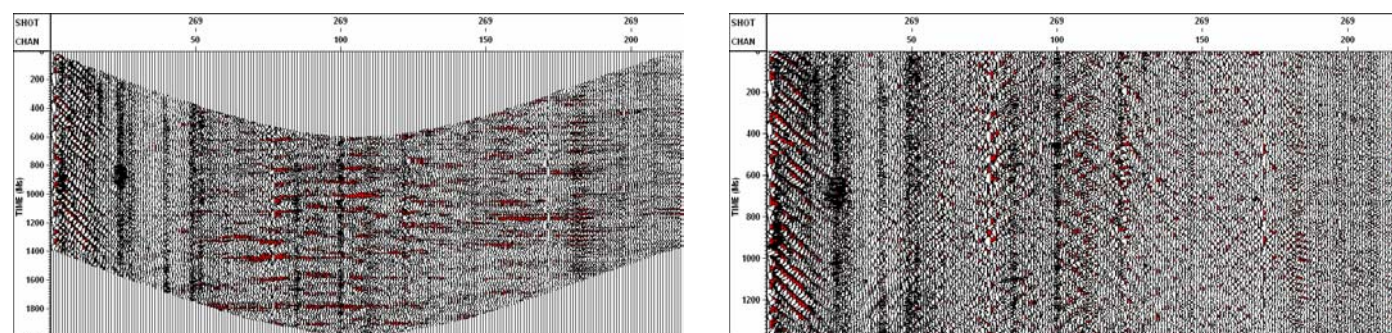

Figure 3) Flattened noise data (a) and filtered passive noise data (b) using a 9 Pt. Mean filter. After filtering only the pump and random noise are left

The same method is applied to shot gathers to suppress the noise (Figure 4.) Once each shot gather has been individually filtered the data is further processed to produce a final stacked section. The processing methodology is identical to that previously used on the data and rerun using the filtered data in place of the original raw data. The results (Figure 5.) illustrate the effectiveness of the filter, especially towards the edges of the stacked section where fold is much lower. The centre of the gather does not change much because stacking of data has removed the noise due to its randomness in time.
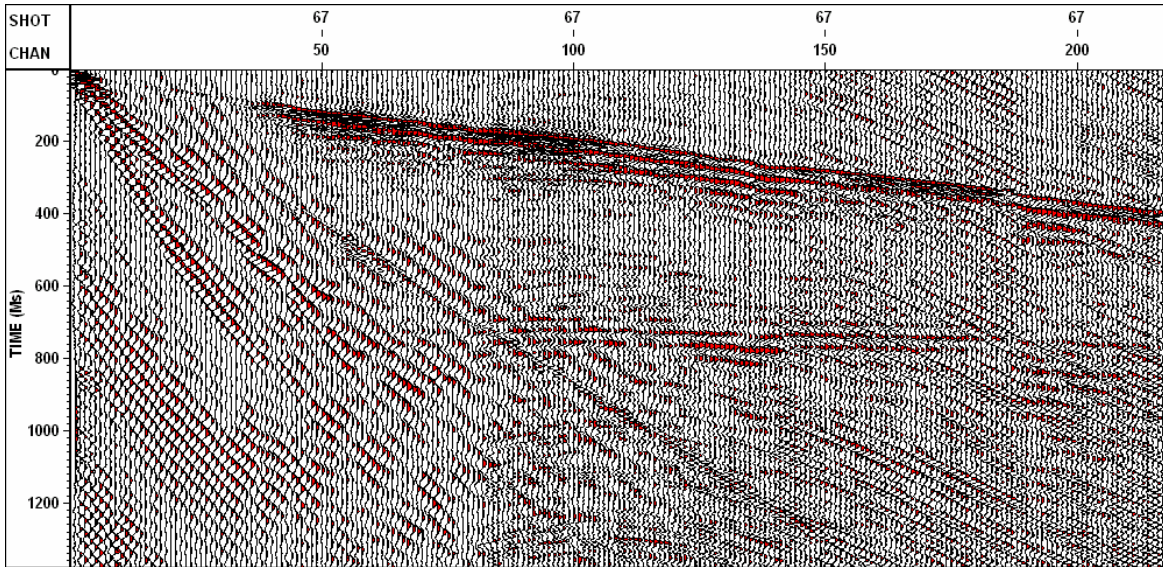
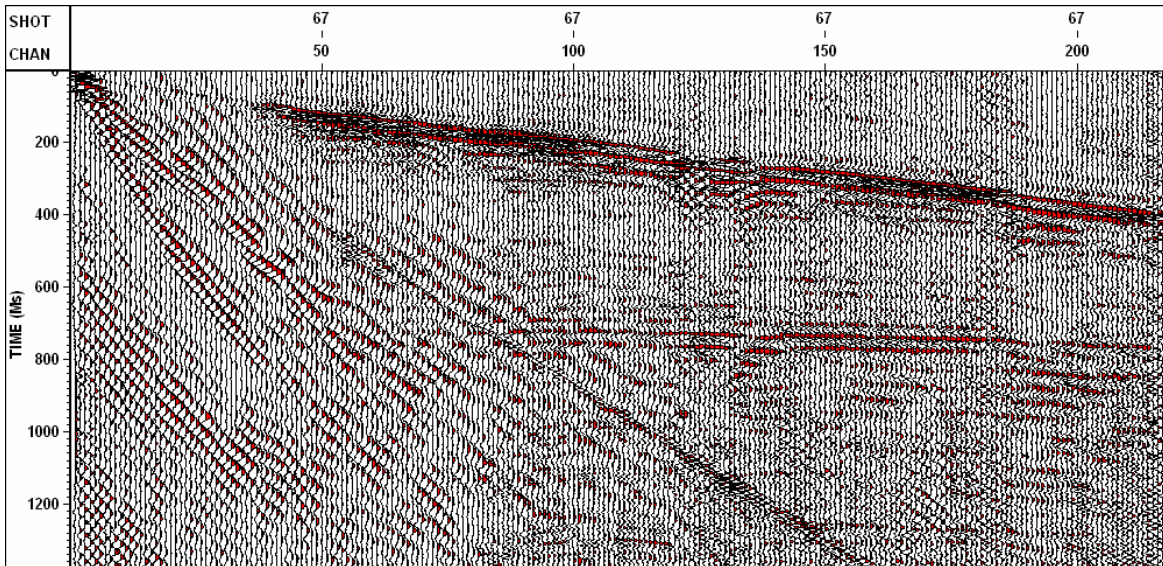**Figure 4a) Raw Shot Gather (AGC Applied)**

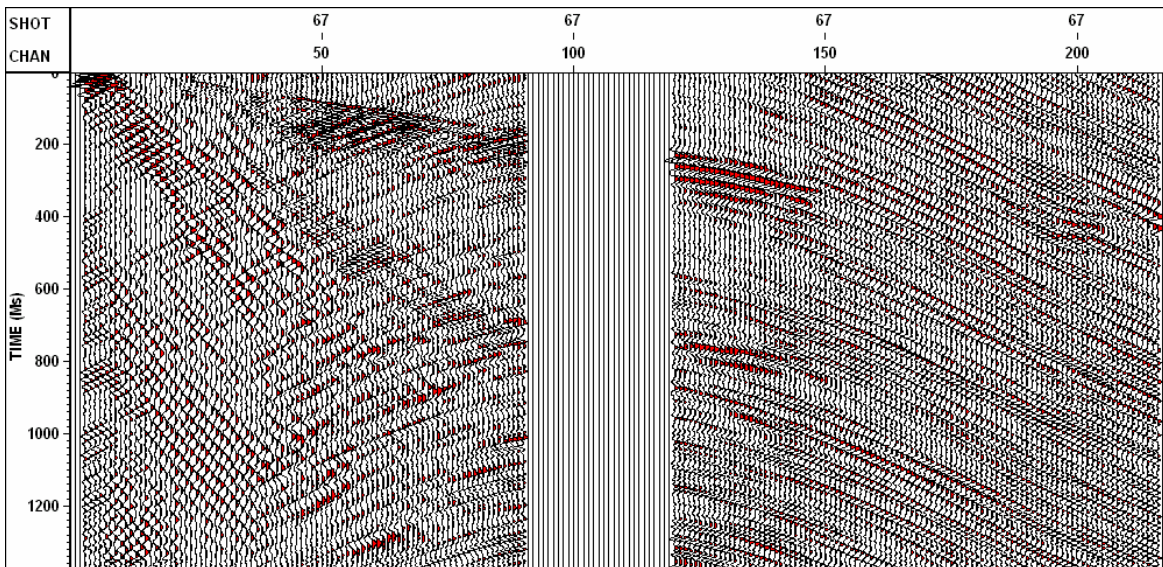**Figure 4b) 9 Point Mean filter applied to the data (AGC Applied)**

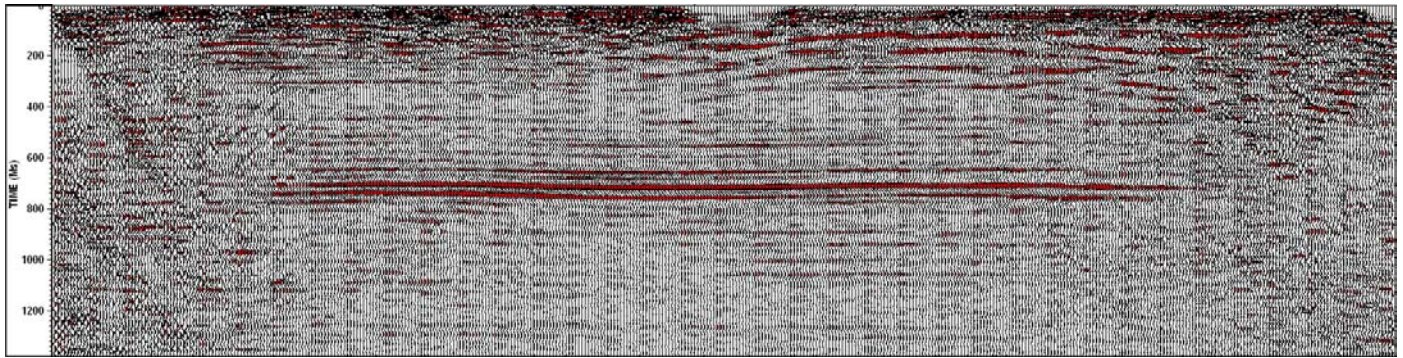**Figure 4c) 9 Point Mean Filter (AGC Applied)**

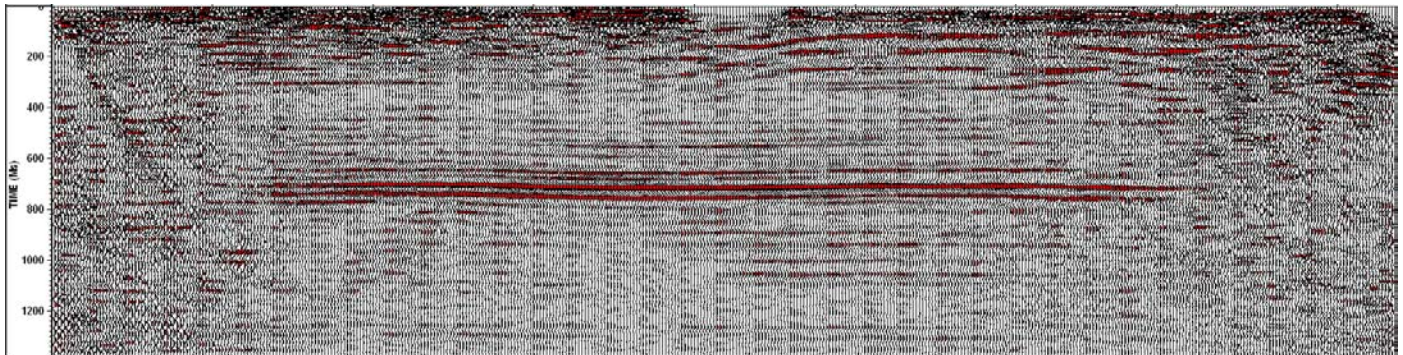**Figure 5a) Unfiltered final stack**

Figure 5b) Final stacked section using 9 Point Mean filtered data.

Two questions remain: 1) What is more effective, use of the median or mean filter and 2) how wide should the filter be?

Filter Choices

If the noise signal was more coherent in amplitude the width would have a smaller effect. In fact the data is very random and the width must be carefully chosen. A wide filter would have almost no effect as the signal would be cancelled out while a narrow filter may be harmful due to a random spike in the noise. Tests were run on filter widths ranging from 5 to 11 traces using both mean and median methods. Visual examination of both, the shot gathers and final stack using the different filters shows the 9 point mean filter to be most effective for this data set. The median is often used in place of the mean or average when there are a number of extreme data values or the distribution of data is skewed. If data has a gaussian distribution the two values should be identical. In the given case lateral variations in amplitude are not extreme and the filter widths are small.

Conclusions

Separation of **desired** and unwanted signal depends on being able to characterise and identify the noise source and signal. Median and mean filters can be effectively used to remove background noise from a seismic shot gather to improve the final stacked sections. The noise signal in this case is random in nature but does have a constant moveout. Sufficient fold or data stacking works well to remove random noise but is insufficient when fold is low. The need to for high resolution is principle in development of the filter especially in lower fold data such as the *poor mans 3d survey* recorded for the same geophone array. As well, more investigation of the variations in the more complete alpha-trim filter needs to be investigated.

Acknowledgements

References

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