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Audit Ground Motion Data Submitted to the BC Energy Regulator

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Executive Summary

In June 2016, the BC Energy Regulator (BCER) published guidelines for ground motion monitoring and submission for the intention of recording ground motion within certain oil and gas development areas in northeast British Columbia (NE BC). Ground motion data have since been submitted to BCER by permit holders operating within the designated area. This study aims at providing a review on the submitted data and evaluate its potential application in induced seismicity research. Both qualitative and quantitative assessments are performed on the submitted data.

This report includes several sections. First, the BCER requirements for data submission are reviewed, followed by an overview of the submitted data. Data provided in different file types are reviewed for its content, format, and quality. The quality of ground motion waveforms is analyzed and a comparison of ground motion values from BCER dataset and publicly available data is made. Finally, recommendations are provided on how to improve the process of data collection from private seismic networks in the area.

Review of the submitted data show that the requirements for data submission was not met in many cases. For example, the submission guideline states that PDF reports must be submitted within 30 days of completing fracturing activities, which include information on felt events or recorded motions with amplitudes of 0.008g or higher. However, there are 51 wells with exceeding ground motions above the prescribed threshold of 0.008g, but without any PDF report. The BCER CSV template format was not followed for many of the submitted CSV files. Out of 532 submitted CSV files only 82 of them (15%) follow the template whereas 450 files (85%) have different formats than the template. From 108 wells with SEED files, 9 wells include

corrupted files (58 files). Review of the header of ground motion files show that basic information is available in each file. However, none of the ground motion files include information about recorded earthquakes. Moreover, station information is not available for 795 ground motion files (out of 2605 files).

Review of ground motion waveforms show that data quality varies significantly among recordings. While there are cases with clear seismic signals (both P and S waves) within very low background noise level, there are ground motion recordings with very high background noise level obscuring seismic signals or data that show glitch in the recoding instrument. Analysis of attenuation of ground motion amplitudes with distance show that spectral acceleration values were not correctly calculated. Moreover, comparison between ground motion data from publicly available stations and the submitted data to BCER shows that both datasets extend to a similar close-distance range, although there are more data from the BCER dataset than the public dataset.

Based on the review of submitted data to BCER, it is recommended that BCER publish a guideline on the best practices in seismological data acquisition and processing suitable for induced seismicity research. Specifically, this guideline should include the following topics:

1) Methodology to calculate response spectral acceleration.

2) Standard for seismic network design to ensure the highest waveform quality is achieved. This includes strategies to generate simulated detection maps and background noise tests prior to installing seismic stations in the field.

3) Currently, the BCER spreadsheet template shows %g and cm/sec^2 as units for acceleration while the submission guideline mentions acceleration in fraction of g such as 0.008g. It is

recommended that both the spreadsheet template and submission guideline use the same unit for ground motion.

4) The submission guideline only includes the North Peace Ground Motion Monitoring Area as the designated area where permit holders are required to submit data. However, most submitted data are from the Kiskatinaw Seismic Monitoring and Mitigation Area in southern Montney play. Therefore, it is recommended that BCER include KSMMA in the submission guideline as well.

BCER Submission Guidelines

According to the BCER guideline (https://www.bc-er.ca/files/operations-documentation/Induced-Seismicity-Data-and-Submission/Ground-Motion-Monitoring-and-Submission-Guideline.pdf) for ground motion monitoring and submission, permit holders must have adequate ground motion monitoring during hydraulic fracturing within the designated area (Figure 1) and submit a ground motion monitoring report (in PDF format) within 30 days of completing fracturing activities. A minimum of 1 ground motion monitoring station, capable of recording ground motion acceleration of 0.005g or higher with a clipping level of ± 2 g, must be installed within 3 km of the common drilling pad. At any time during injection (and during flowback if monitoring is on-going), if a felt event occurs or the ground motion monitoring station(s) record ground motion acceleration of 0.008g or higher, this information should be included in the report. This additional information must be submitted as CSV and SEED files. CSV files, using the BCER template (https://www.bc-er.ca/files/operations-documentation/Induced-Seismicity-Data-and-Submission/ground-motion-reporting-template-july-release-2016.xlsx), contain information on events and ground motion parameters including peak ground acceleration, PGA, peak ground

velocity, PGV, and 5% damped spectral acceleration, SA. Guidelines on calculating these ground motion parameters are included in a separate document (https://www.bc-er.ca/files/operations-documentation/Induced-Seismicity-Data-and-Submission/Calculation_ground_motion_parameters_edited.pdf). SEED files include both the waveform, with a window encompassing 30 sec before the event and 60 sec after, and instrument response.

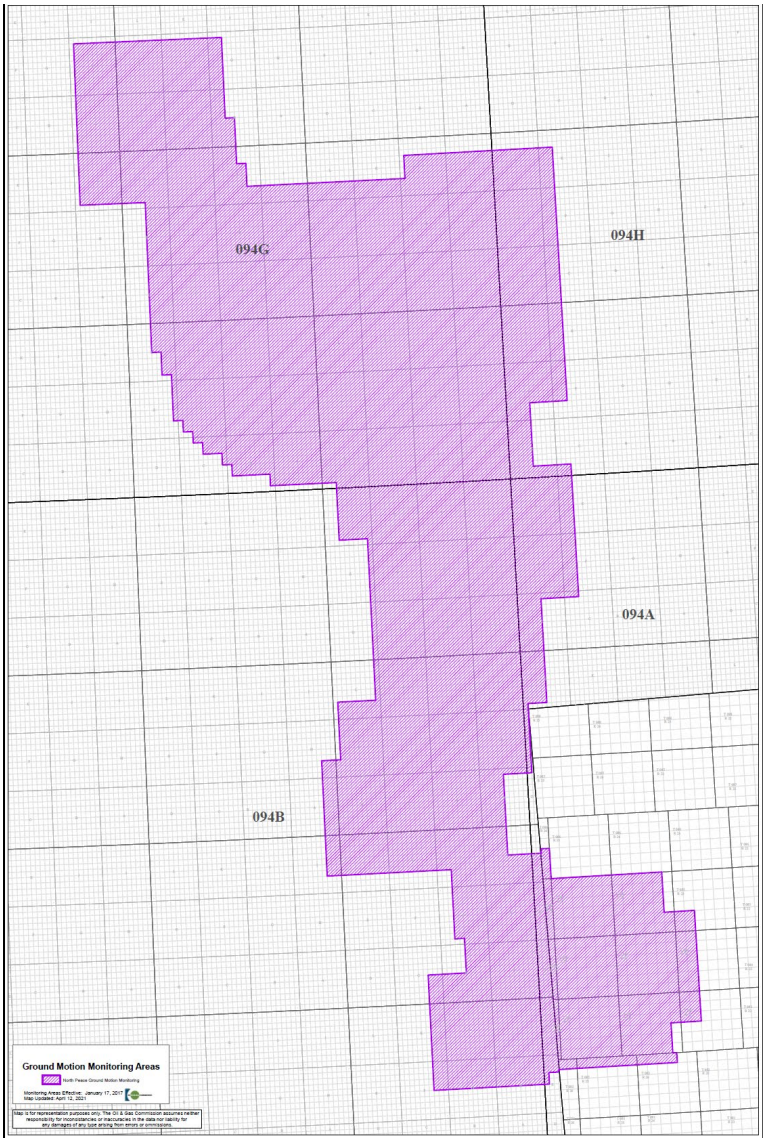

Figure 1. Ground motion monitoring area proposed by BCER.

Data Overview

Well data were searched in the BCER eLibrary (https://files.bc-er.ca/ThinClient/WTM/public/index.html#/login) via FileZilla through searching for keyword "GMMR". This resulted in 1658 files (as of September 7, 2024) including PDF, CSV, and SEED formats. Files were transferred to a local machine from the eLibrary. Figure 2 shows a screenshot of data transfer.

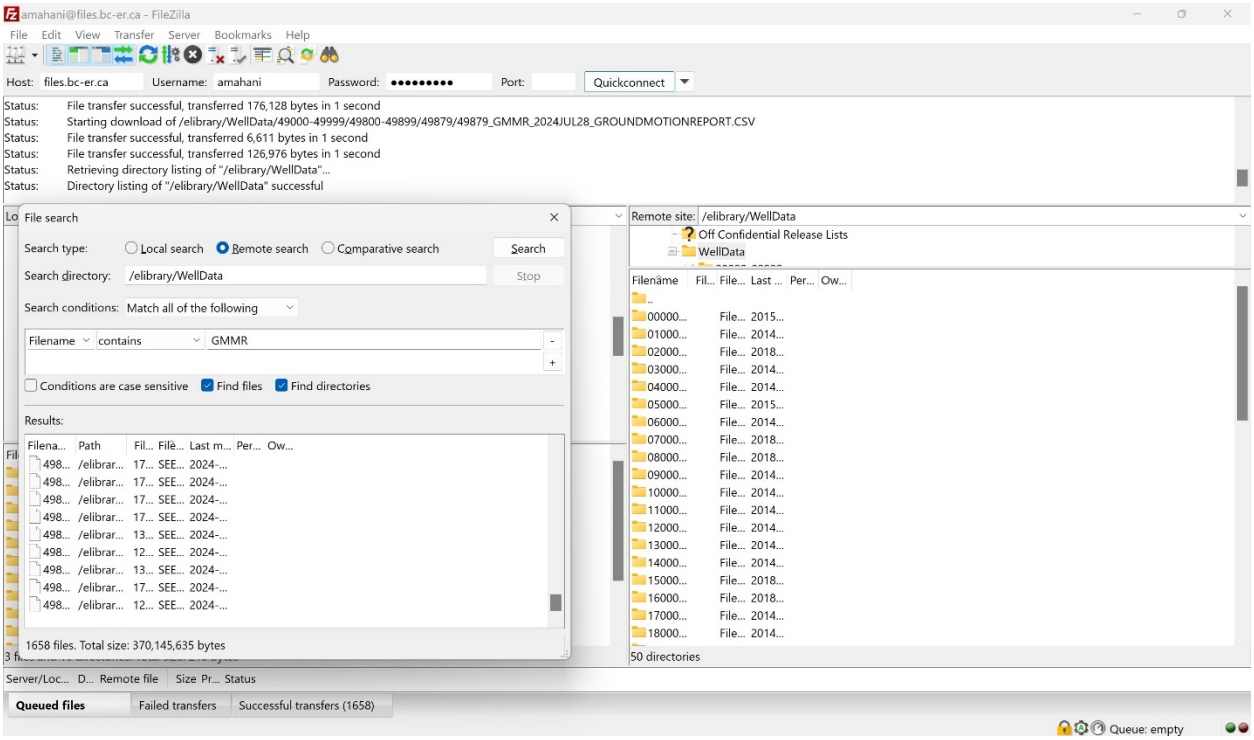

Figure 2. Screenshot of the data search and transfer using FileZilla from BCER eLibrary.

File naming of the submitted well data is according to the submission guidance by BCER. Each file starts with the WA number, followed by the keyword GMMR and date in the following format: WANUM_GMMR_YYYYMMMDD_OPTIONALDESCRIPTION.PDF/CSV/SEED.

There are 287 PDF files, 532 CSV files, and 839 SEED files from 318 wells. Table A in the first appendix shows the number of CSV, PDF, and SEED files for each well, identified by the WA number. Table 1 shows a summary of the information shown in Table A. In Table 1, S stands for SEED file, P for PDF, C for CSV, and N for Nill (not available). For example, there are 14 wells for which SEED files are available but neither PDF nor CSV files accompany these SEED files. Figure 3 plots the data shown in Table 1.

Table 1. Permutation of file availability for the wells. S = SEED, P = PDF, C = CSV, Nill = not available.

Permutation	Count
SPC	53
SNC	36
SPN	5
SNN	14
NPC	6
NNC	1
NPN	203

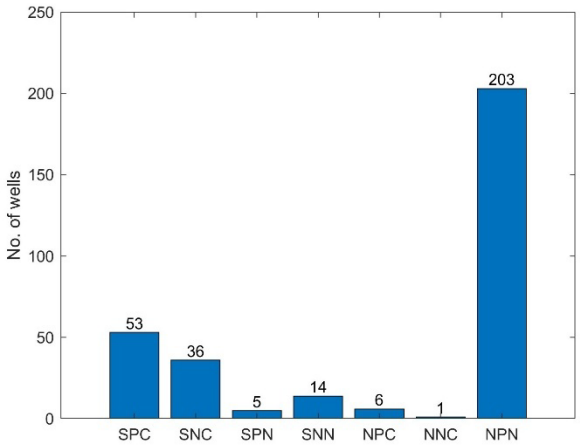

Figure 3. Permutation of file availability for the wells (from Table 1). S = SEED, P = PDF, C = CSV, Nill = not available.

CSV Files

Review of the CSV file headers, based on BCER's spreadsheet template, show that out of 532 submitted CSV files only 82 of them (15%) follow the template whereas 450 files (85%) have different formats than the template. The differences between the format of submitted CSV files and the template range from minor differences (for example, extra column for providing PGA in m/sec^2 or fraction of g) to completely different CSV files than the one provided by the template. This makes it difficult for systematic data extraction from files as some manual data manipulation would be required. Note that although the guidance for ground motion monitoring and submission by BCER indicates fraction of g as the preferred unit to present ground motion acceleration (for example, 0.008g), the spreadsheet template indicates %g, which could result in confusion.

To dig deeper into the state of submitted data and understand the amount of seismological information provided by private seismic networks, data from each CSV file with its header matching the header of the BCER's template was extracted. Overall, there are 782 ground motion entries from 82 CSV files. However, only 338 entries provide a complete picture of seismological data that can be used for research (i.e., each entry has station location, event magnitude and location, and ground motion parameters including PGA, PGV, and SA for three components). The ground motion data compiled from these CSV files are presented in the file ground_motion_data.xlsx accompanied to this report. Figure 4 shows the location of earthquakes and stations. An interesting observation from Figure 4 is that data from only three earthquakes and one station are from the North Peace Ground Motion Monitoring Area (NPGMMA) which is the designated area in the BCER submission guideline shown in Figure 1. Most submitted data

are from the Kiskatinaw Seismic Monitoring and Mitigation Area (KSMMA) in the southern Montney play.

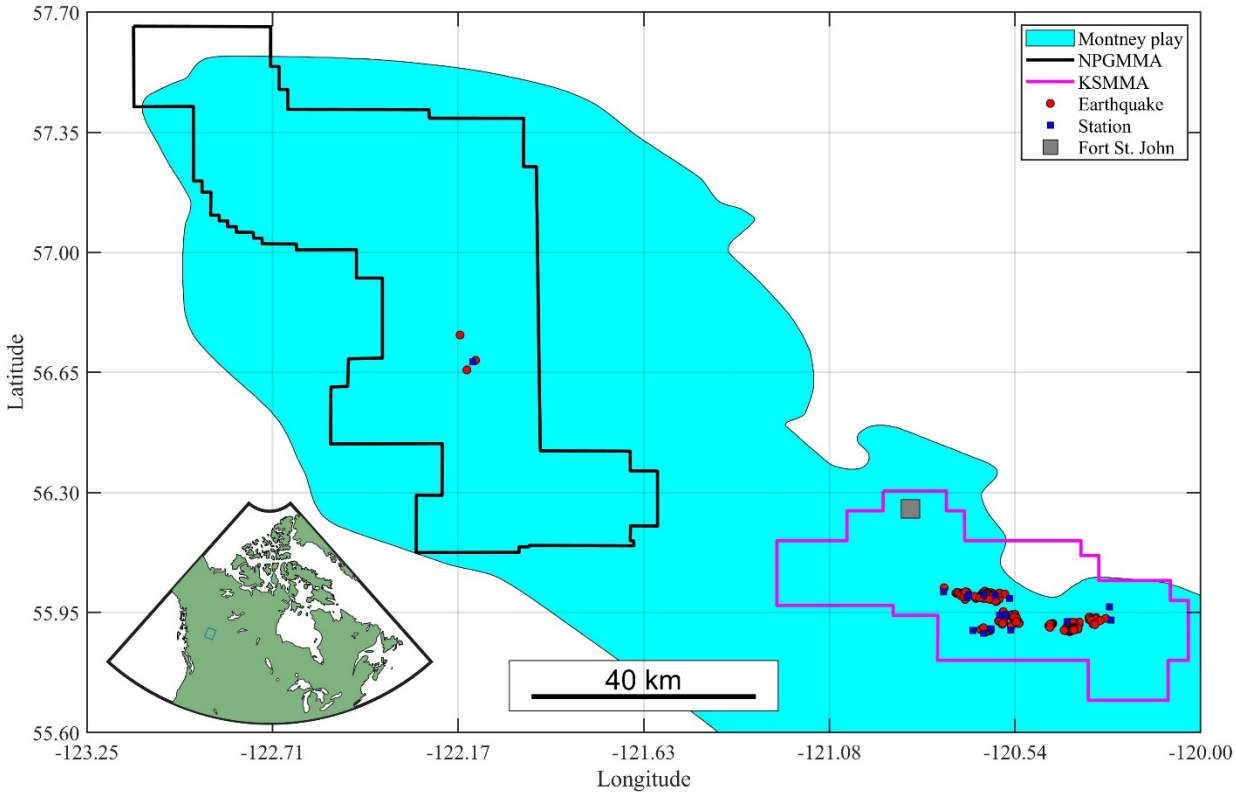

Figure 4. Distribution of earthquakes and seismic stations from the CSV files submitted to BCER.

Figures 5-7 show ground motion amplitudes (PGA, PGV, and SA) versus epicentral distance for the two horizontal (H1 and H2) and vertical components, respectively. As can be seen from these figures, PGA and PGV show a “normal” attenuation of ground motion versus distance. However, there seems to be some issues with the spectral acceleration data as they show some clustering of ground motions that does not seem to represent correct attenuation of ground motion.

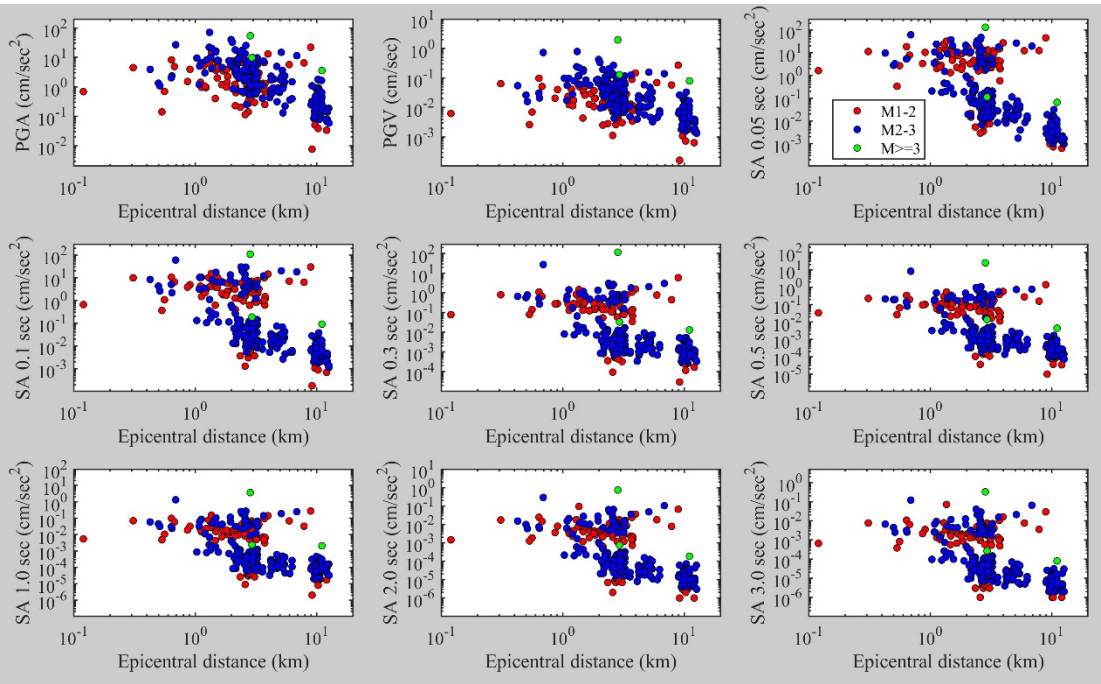

Figure 5. Ground motion amplitude versus epicentral distance grouped into three magnitude bins for the H1 component.

SEED Files

There are 108 wells (out of 318) with SEED files (https://ds.iris.edu/ds/nodes/dmc/data/formats/seed/). SEED files were converted into a format called Seismic Analysis Code (SAC; https://ds.iris.edu/ds/nodes/dmc/software/downloads/sac/) for further processing of waveforms. Station metadata was also obtained in the RESP format (https://ds.iris.edu/ds/nodes/dmc/data/formats/resp/). The program RDSEED (https://github.com/iris-edu-legacy/rdseed) was used for data conversion with the following commands:

RDSEED -t -f [SEED file name] > info_[SEED file name].txt

RDSEED -R -d -o 1 -f -I [SEED file name]

From 108 wells with SEED files, 9 wells include corrupted SEED files (58 files) that were not converted to SAC. Table 2 shows these wells.

Table 2. List of wells with corrupted SEED files.

WA number
30037
30091
30712
30741
32027
34713
38816
38822
39338

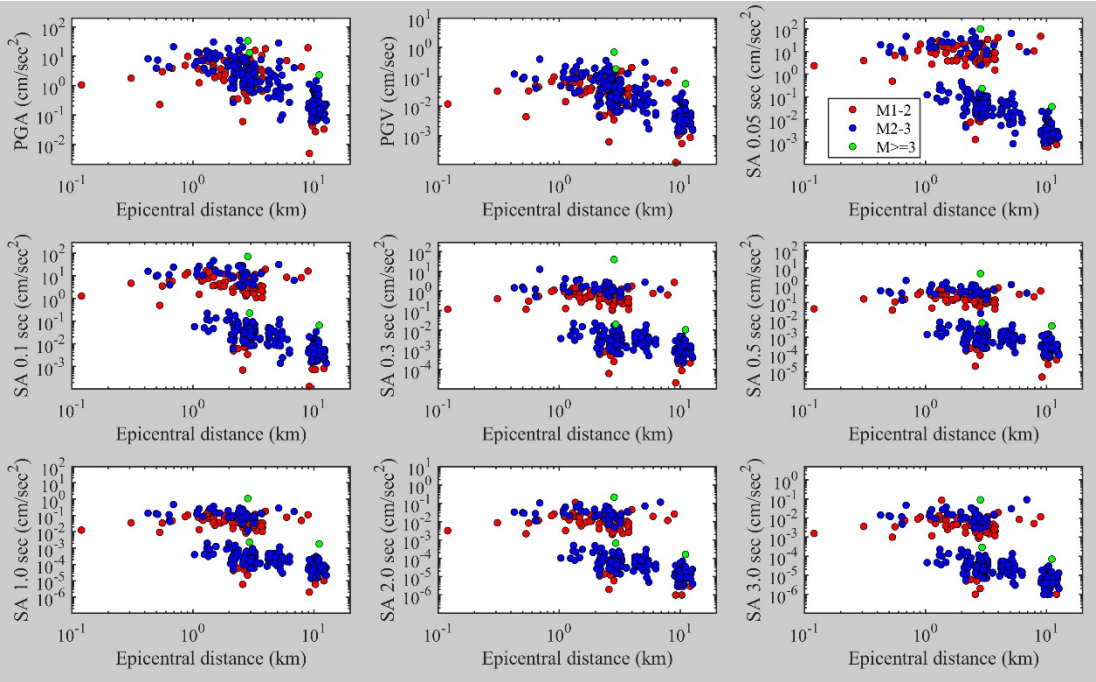

Figure 6. Ground motion amplitude versus epicentral distance grouped into three magnitude bins for the H2 component.

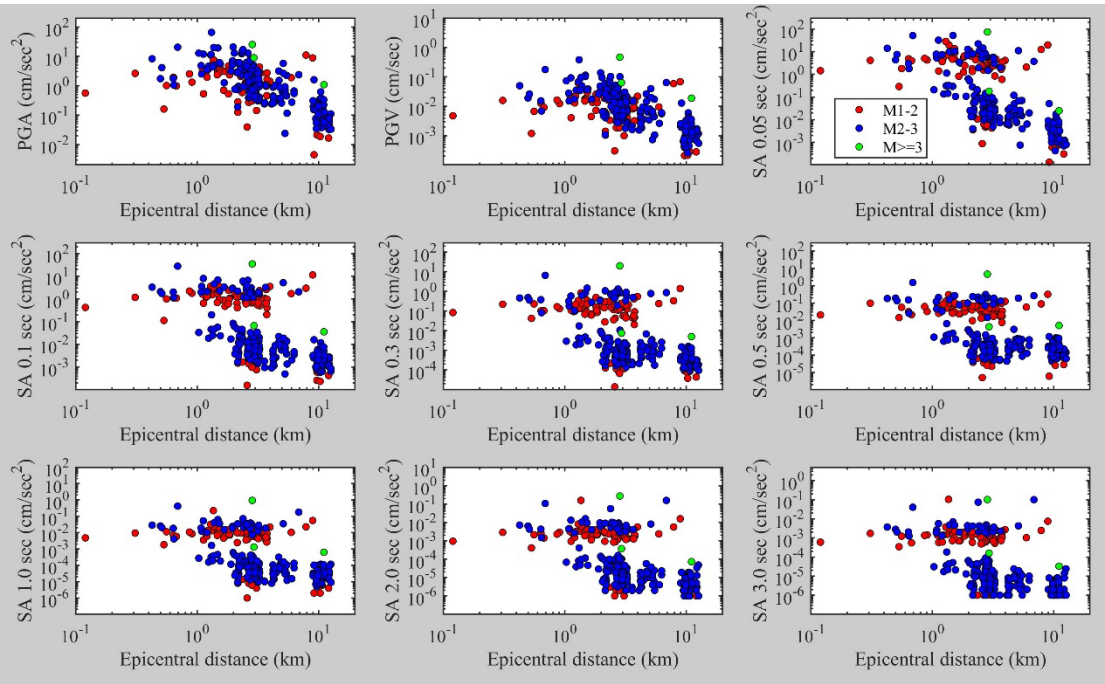

Figure 7. Ground motion amplitude versus epicentral distance grouped into three magnitude bins for the vertical component.

Overall, there are 2605 SAC files from 99 wells without corrupted SEED files. Table B in the second appendix provides the number of SAC and SEED files for each well. Wells with corrupted SEED files are shown in bold.

Review of the SAC header files show that basic information including sampling interval, station name, network name, and channel name are available from all SAC files. However, none of the SAC files include event information (latitude, longitude, magnitude, and depth). Moreover, station information (latitude, longitude) is not available for 795 SAC files from wells 30209, 31243, 31246, 31862, 33680, 33857, 34786, 34789, 34790, 35804, 35836, 35844, 35847, 35849, 35951, 35954, 35955, 35956, 35957, 36001.

Ground Motion Data Quality

Manual review of raw waveforms show that they have a wide range of quality. The ideal case includes waveforms with clear earthquake signals recorded within a very low background noise for which all seismic phases are captured in the submitted file (P, S, Surface, and coda waves) and the onset of P wave can be clearly distinguished. An example of this idea case is shown in Figure 8. Examples of waveforms with other qualities are shown in Figures C1-C4 in the third appendix.

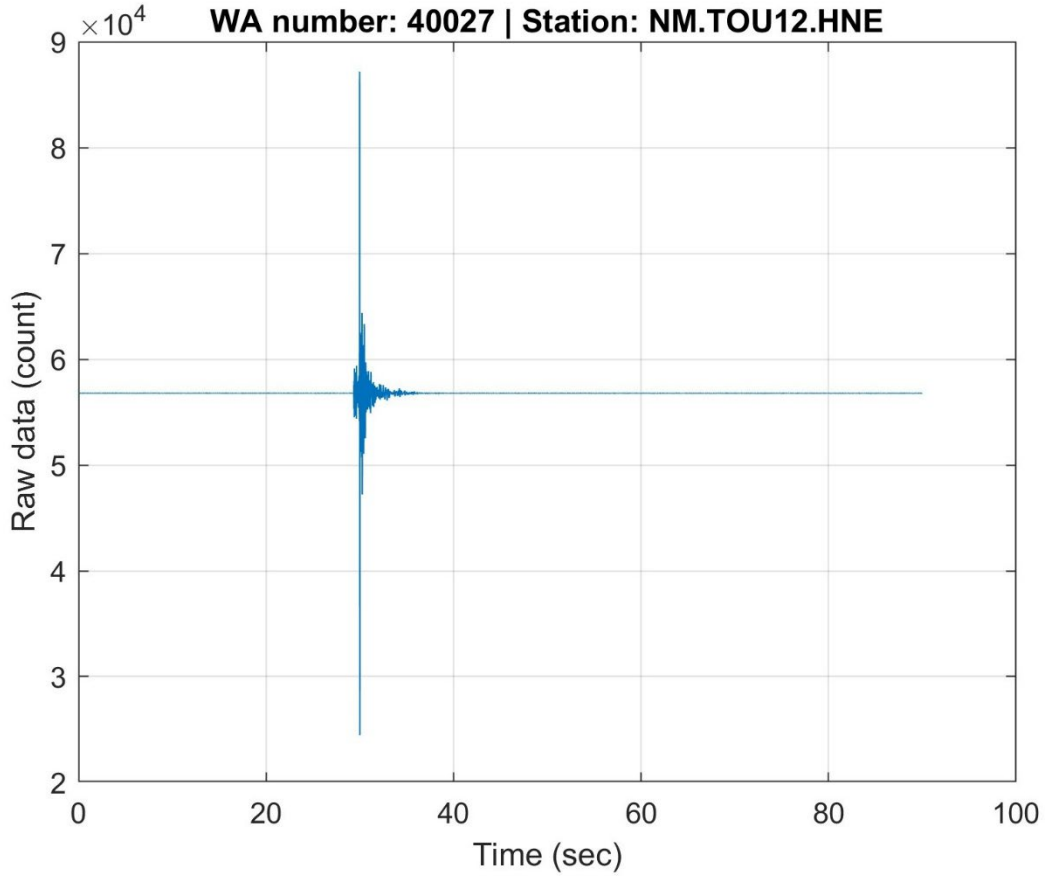

Figure 8. Example of a recorded waveform with earthquake signals clearly visible within a very low background noise. This is an ideal quality for seismological research as the onset of seismic phases can be determined. Moreover, the entire waveform is captured within the file.

Comparison with Public Data

Figure 9 compares attenuation of PGA versus distance between the data submitted to BCER (as obtained from the CSV files explained above) and the data obtained from public stations in NE BC. PGA values are grouped into two magnitude bins 2.0-2.5 and 2.5-3.0 (there are not enough data points for magnitudes > 3.0 in the BCER dataset). As can be seen from Figure 9, there is good agreement in ground motion amplitudes between BCER and public datasets. Moreover, both datasets show similar data coverage at close distances. This is due to the densification of the public seismic networks in NE BC since 2013 (Salas et al., 2013; Salas and Walker, 2014). However, it is evident that there are more data points from the BCER dataset than the public dataset.

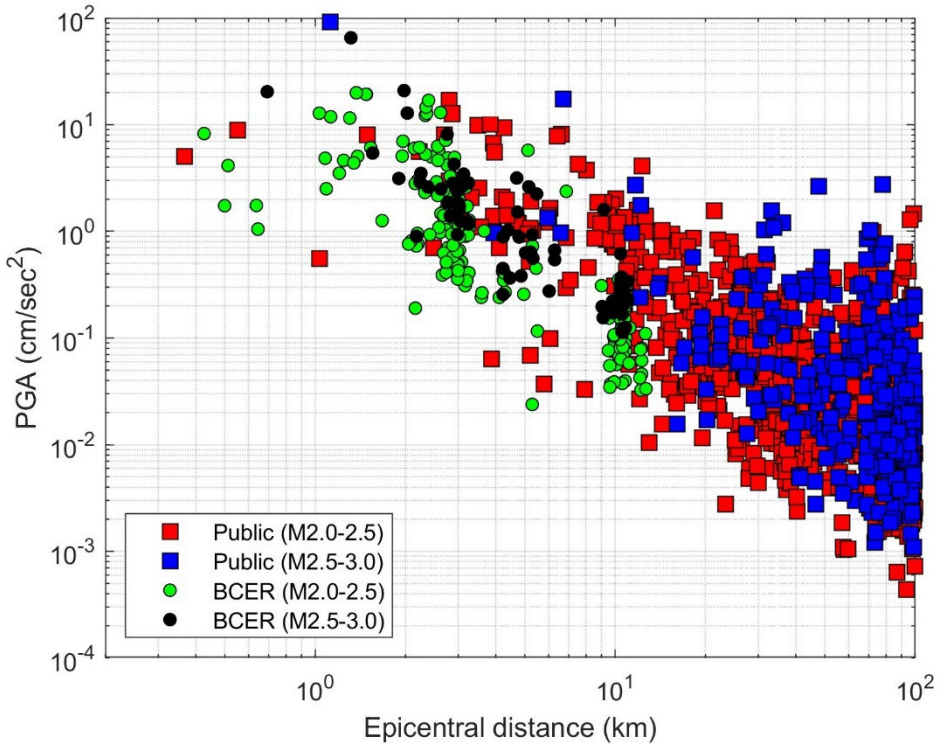

Figure 9. Comparison of the attenuation of PGA versus distance between public and BCER datasets for two magnitude bins 2.0-2.5 and 2.5-3.0.

Figure 10 shows the comparison between public and BCER datasets for SA at 0.1 sec. As mentioned above in Figures 5-7, SA values from BCER datasets were not correctly calculated, which can also be seen in Figure 10.

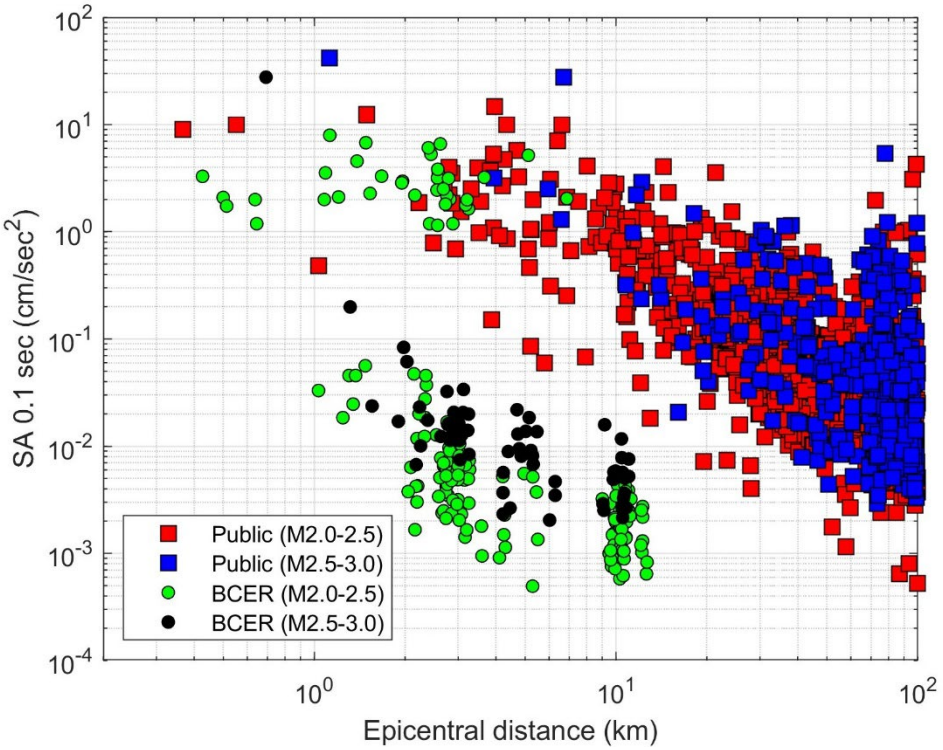

Figure 10. Comparison of the attenuation of SA at 0.1 sec versus distance between public and BCER datasets for two magnitude bins 2.0-2.5 and 2.5-3.0.

Discussion and Recommendation

Research into induced seismicity processes require data from various sources. Since 2013, the provincial, federal, academia, and private sectors have invested significantly in NE BC to provide infrastructure for monitoring of induced seismicity from oil and gas activities. As a result, data from seismic monitoring stations are publicly available and have been used in many

research activities in the past decade (e.g., Babaie Mahani et al., 2016; Babaie Mahani and Kao, 2019; Babaie Mahani, 2021; Babaie Mahani et al., 2021). Besides the available data from public stations, permit holders have also invested heavily in seismic monitoring, which has significant potential to enhance the datasets required for detailed analysis of induced seismicity process. As can be seen from Figure 9, although the distance coverage is similar between the publicly available data and those submitted to BCER by permit holders, there are more data points from the BCER dataset at close distances. This highlights the importance of submitted data to BCER as the additional information from private networks can be used in different research opportunities. Since private stations are usually installed very close to injections (and, therefore, to earthquake sources), waveforms can be used to constrain earthquake source parameters such as hypocentral depth. Moreover, they can be used to constrain the variability of near-field ground motion amplitudes (ground motions at close distances) and ground motion characteristics for different site conditions and, therefore, reducing the uncertainty associated with ground motion prediction equations.

Although the additional ground motion data from private networks are certainly useful for research opportunities, their quality and compatibility to other available datasets should be considered as well. This means that guidelines should be in place to ensure that the quality of submitted data adhere to the standards needed for seismological research. For example, as mentioned in the report, response spectral acceleration was not correctly estimated in the submitted data to BCER, which makes it impossible to incorporate this data to the ones available from other sources. Other issues with the submitted data include waveforms that do not incorporate the least amount of header information such as station location. A systematic data acquisition and processing scheme must be in place to make use of the abundant, privately

owned seismic data. Standard formats for data repository and processing of ground motion data are available within the seismological community and can be accessed from sources such as the Incorporated Research Institutions for Seismology (IRIS) (has merged with UNAVCO to form the EarthScope Consortium).

Based on the review of submitted data to BCER, it is recommended that BCER publish a guideline on the best practices in seismological data acquisition and processing suitable for induced seismicity research. Specifically, this guideline should include the following topics:

1) Methodology to calculate response spectral acceleration.

2) Standard for seismic network design to ensure the highest waveform quality is achieved. This includes strategies to generate simulated detection maps and background noise tests prior to installing seismic stations in the field.

3) Currently, the BCER spreadsheet template shows %g and cm/sec^2 as units for acceleration while the submission guideline mentions acceleration in fraction of g such as 0.008g. It is recommended that both the spreadsheet template and submission guideline use the same unit for ground motion.

4) The submission guideline only includes the North Peace Ground Motion Monitoring Area (Figure 1) as the designated area where permit holders are required to submit data. However, most submitted data are from the Kiskatinaw Seismic Monitoring and Mitigation Area in southern Montney play. Therefore, it is recommended that BCER include KSMMA in the submission guideline as well.

Conclusion

This report provided a review of ground motion data submitted to BCER in accordance with its 2016 guidelines. Review of the submitted data show that the requirement for data submission was not met in many cases. For example, there are 51 wells for which ground motions were exceeded above the prescribed thresholds of 0.008g but no PDF report was submitted. The BCER CSV template format was not followed for many of the submitted CSV files. Out of 532 submitted CSV files only 82 of them (15%) follow the template whereas 450 files (85%) have different formats than the template. From 108 wells with SEED files, 9 wells include corrupted SEED files (58 files). Review of the header of ground motion files show that basic information is available in each file. However, none of the ground motion files include information about recorded earthquakes. Moreover, station information is not available for 795 ground motion files (out of 2605 files).

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Acknowledgements

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References

Babaie Mahani, A., H. Kao, D. Walker, J. Johnson, and C. Salas (2016). Performance Evaluation of the Regional Seismograph Network in Northeast British Columbia, Canada, for Monitoring of Induced Seismicity, Seismological Research Letters, V. 87, No. 3, p. 648-660, https://doi.org/10.1785/0220150241

Babaie Mahani, A. and H. Kao (2019). Accurate Determination of Local Magnitude for Earthquakes in the Western Canada Sedimentary Basin, Seismological Research Letters, Vol. 90, No. 1, p. 203-211, https://doi.org/10.1785/0220180264

Babaie Mahani, A. (2021). Seismic b-value within the Montney Play of Northeast British Columbia, Canada, Canadian Journal of Earth Sciences, Vol. 58, No. 8, p. 720-730, https://doi.org/10.1139/cjes-2020-0157

Babaie Mahani, A., S. Venables, H. Kao, R. Visser, M. Gaucher, R. M. H. Dokht, and J. Johnson (2021). Intensity of Induced Earthquakes in Northeast British Columbia, Canada, Seismological Research Letters, Vol. 92, No. 6, p. 3482-3491, https://doi.org/10.1785/0220210037

Salas, C. J., D. Walker, and H. Kao (2013). Creating a regional seismograph network in northeast British Columbia to study the effect of induced seismicity from unconventional gas completions (NTS 094C, G, I, O, P), Geoscience BC Summary of Activities 2012, Geosci. BC, Rept. 2013-1, 131–134.

Salas, C. J., and D. Walker (2014). Update on regional seismograph network in northeastern British Columbia (NTS 094C, G, I, O, P), in Geoscience BC Summary of Activities 2013, Geosci. BC, Rept. 2014-1, 123–126.

Appendix 1

Table A. Number of CSV, PDF, and SEED files for each well, identified by the WA number.

No. of CSV	No. of PDF	No. of SEED	WA No.
0	1	0	20897
0	1	0	26894
1	1	0	27022
0	1	0	27147
0	1	0	27359
0	1	0	28247
0	1	0	29234
0	0	1	29426
1	1	2	29429
0	1	0	29439
0	0	2	29459
0	0	1	29460
0	2	0	29514
1	1	2	29725
0	1	0	29851
0	1	0	29967
1	1	6	30037
0	1	0	30087
0	1	1	30091
0	1	0	30194
0	1	0	30195
1	0	21	30209
0	1	0	30266
0	1	0	30305
0	2	0	30309
0	1	0	30310
0	1	0	30311
0	2	0	30312
0	1	0	30313
1	1	1	30327
0	1	0	30420
0	1	1	30712
2	1	2	30741
0	1	0	30795
1	1	5	30858
0	1	0	30863
1	1	5	31095
0	1	0	31131

2	0	8	31139
1	0	1	31209
1	0	6	31243
0	0	2	31246
0	1	0	31283
1	1	3	31336
0	1	0	31436
1	1	15	31486
0	1	0	31529
0	1	0	31577
2	1	13	31588
1	0	35	31619
0	2	0	31660
0	1	0	31664
0	1	0	31669
1	1	1	31702
0	1	0	31713
0	1	0	31735
0	1	0	31750
0	1	0	31805
5	2	10	31806
0	1	0	31810
0	1	0	31834
1	0	1	31862
0	1	0	31877
0	1	0	31964
0	1	0	32002
0	1	0	32003
0	1	0	32004
0	1	0	32005
1	0	3	32022
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0	1	0	32054
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0	1	0	32068
1	1	2	32248
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0	1	0	32292
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0	1	0	32294
3	3	17	32301
0	0	1	32305
0	1	0	32439

0	1	0	32440
0	1	0	32441
0	1	0	32442
0	1	0	32446
0	1	0	32447
0	1	0	32448
405	0	6	32483
1	0	4	32485
0	1	0	32520
0	1	0	32522
0	1	0	32523
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0	1	0	32525
0	1	0	32528
0	1	0	32529
0	1	0	32581
1	1	6	32582
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1	3	0	32768
0	1	0	32772
0	1	0	32866
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0	2	0	32908
0	2	0	32922
0	1	0	32938
1	0	1	32950
0	1	0	33003
0	1	0	33085
0	1	0	33113
1	1	0	33137
0	1	0	33154
0	1	0	33155
0	1	0	33156
0	1	0	33157
1	0	4	33161
1	0	1	33169
1	0	1	33171

1	0	1	33172
2	0	2	33173
3	0	3	33176
0	1	0	33286
0	1	0	33287
0	1	0	33288
0	1	0	33289
0	1	0	33294
0	1	0	33295
0	1	0	33345
0	1	0	33346
0	1	0	33347
1	1	5	33348
0	1	0	33387
1	0	2	33407
1	1	1	33422
1	1	1	33423
0	1	0	33502
0	1	0	33503
0	1	0	33507
1	1	1	33579
0	1	0	33659
0	1	0	33660
0	1	0	33661
1	1	1	33662
2	2	4	33663
0	1	0	33664
1	1	1	33665
1	1	1	33666
1	1	4	33667
0	1	0	33668
1	0	12	33680
0	1	0	33742
0	1	0	33743
0	1	0	33745
0	1	0	33746
0	1	0	33747
0	1	0	33748
0	1	0	33772
0	1	0	33784
1	0	5	33857
0	1	0	33976
0	1	0	34034

0	2	0	34090
0	1	0	34149
0	1	0	34214
0	1	0	34215
0	1	0	34220
0	1	0	34221
0	1	0	34241
0	1	0	34242
1	1	2	34280
0	1	0	34287
0	1	1	34713
0	1	0	34714
0	1	0	34715
0	1	0	34716
0	1	0	34717
0	1	0	34718
0	1	0	34719
0	1	0	34720
0	1	0	34721
0	1	0	34722
0	1	0	34723
0	1	0	34724
0	1	0	34737
0	1	0	34739
0	1	0	34740
0	1	0	34741
0	1	0	34742
0	1	0	34744
0	1	0	34745
0	1	0	34746
0	1	0	34747
0	1	0	34748
0	1	0	34749
0	1	0	34750
2	2	25	34786
0	0	11	34789
0	0	2	34790
0	1	0	34966
0	1	0	34967
0	1	0	34968
0	1	0	34969
0	1	0	34970
0	1	0	34971

0	1	0	34972
0	1	0	34973
0	1	0	35019
0	1	0	35131
0	1	0	35132
0	1	0	35133
0	1	0	35134
0	1	0	35135
0	1	0	35136
0	1	0	35137
0	1	0	35138
1	0	11	35240
0	1	0	35321
0	1	0	35332
1	1	1	35410
2	0	2	35415
0	0	2	35416
0	1	0	35446
0	1	0	35448
0	1	0	35457
0	0	12	35804
1	0	16	35836
1	1	34	35844
6	2	28	35847
2	2	64	35849
1	1	6	35951
1	1	4	35954
1	1	6	35955
1	1	2	35956
1	1	10	35957
2	1	8	36001
0	1	0	36126
1	0	21	36163
1	0	5	36265
1	1	6	36292
10	1	0	36406
1	0	14	36414
1	0	46	36431
1	0	4	36489
0	0	5	36491
1	0	2	36663
1	0	8	36692
1	1	0	36909

1	0	6	36975
1	1	4	37008
1	0	2	37091
0	0	1	37114
1	1	3	37115
0	1	0	37131
1	0	0	37149
0	0	6	37152
0	1	0	37589
1	1	14	37601
0	1	0	37904
0	1	0	37940
0	1	0	38019
0	1	0	38174
0	1	0	38196
0	1	0	38552
1	1	0	38765
0	1	0	38771
1	0	5	38816
1	0	2	38822
0	1	0	38999
0	1	0	39000
0	1	0	39055
0	1	0	39063
0	1	0	39162
0	1	0	39226
0	1	0	39258
1	1	4	39284
0	0	1	39286
1	1	5	39315
1	1	39	39338
0	1	0	39482
0	1	0	39548
0	1	0	39604
1	1	4	39758
0	2	1	39942
1	1	5	40027
0	1	0	40167
0	1	0	40213
1	2	8	40227
0	1	0	40402
0	1	0	40515
0	1	0	40521

0	1	0	40639
0	1	1	40651
0	1	0	41123
2	2	8	41154
0	1	0	41212
0	1	0	41310
0	1	0	41328
1	1	94	41353
1	2	1	41434
0	0	1	41436
0	1	0	41448
1	1	6	41511
0	1	0	41529
0	1	0	41534
0	1	0	42322
0	1	0	42422
0	1	0	42573
1	0	1	43718
1	0	4	45868
1	0	2	45898
1	1	4	46541
1	1	13	49879

Appendix 2

Table B. Number of SAC and SEED files for each well. Wells with corrupted SEED files are shown in bold (Table 2).

WA number	No. of SEED files	No. of SAC files
29426	1	15
29429	2	39
29459	2	6
29460	1	3
29725	2	6
30037	**6**	**0**
30091	**1**	**0**
30209	21	60
30327	1	3
30712	**1**	**0**
30741	**2**	**0**
30858	5	15
31095	5	15
31139	8	6
31209	1	3
31243	6	6
31246	2	6
31336	3	9
31486	15	45
31588	13	36
31619	35	105
31702	1	3
31806	10	18
31862	1	3
32022	3	9
32027	**1**	**0**
32248	2	6
32301	17	84
32305	1	36
32483	6	120
32485	4	12
32582	6	9
32950	1	24
33161	4	12
33169	1	3
33171	1	3
33172	1	3

33173	2	24
33176	3	9
33348	5	15
33407	2	4
33422	1	3
33423	1	3
33579	1	3
33662	1	3
33663	4	6
33665	1	3
33666	1	3
33667	4	12
33680	12	33
33857	5	15
34280	2	6
34713	**1**	**0**
34786	25	75
34789	11	33
34790	2	6
35240	11	33
35410	1	3
35415	2	93
35416	2	6
35804	12	36
35836	16	48
35844	34	102
35847	28	84
35849	64	192
35951	6	18
35954	4	12
35955	6	18
35956	2	6
35957	10	30
36001	8	24
36163	21	63
36265	5	15
36292	6	9
36414	14	42
36431	46	138
36489	4	12
36491	5	15
36663	2	6
36692	8	24

36975	6	18
37008	4	12
37091	2	6
37114	1	3
37115	3	9
37152	6	18
37601	14	42
38816	**5**	**0**
38822	**2**	**0**
39284	4	12
39286	1	3
39315	5	15
39338	**39**	**0**
39758	4	12
39942	1	3
40027	5	15
40227	8	24
40651	1	3
41154	8	24
41353	94	282
41434	1	3
41436	1	3
41511	6	18
43718	1	3
45868	4	12
45898	2	6
46541	4	12
49879	13	39

Appendix 3

Examples of waveforms with different qualities.

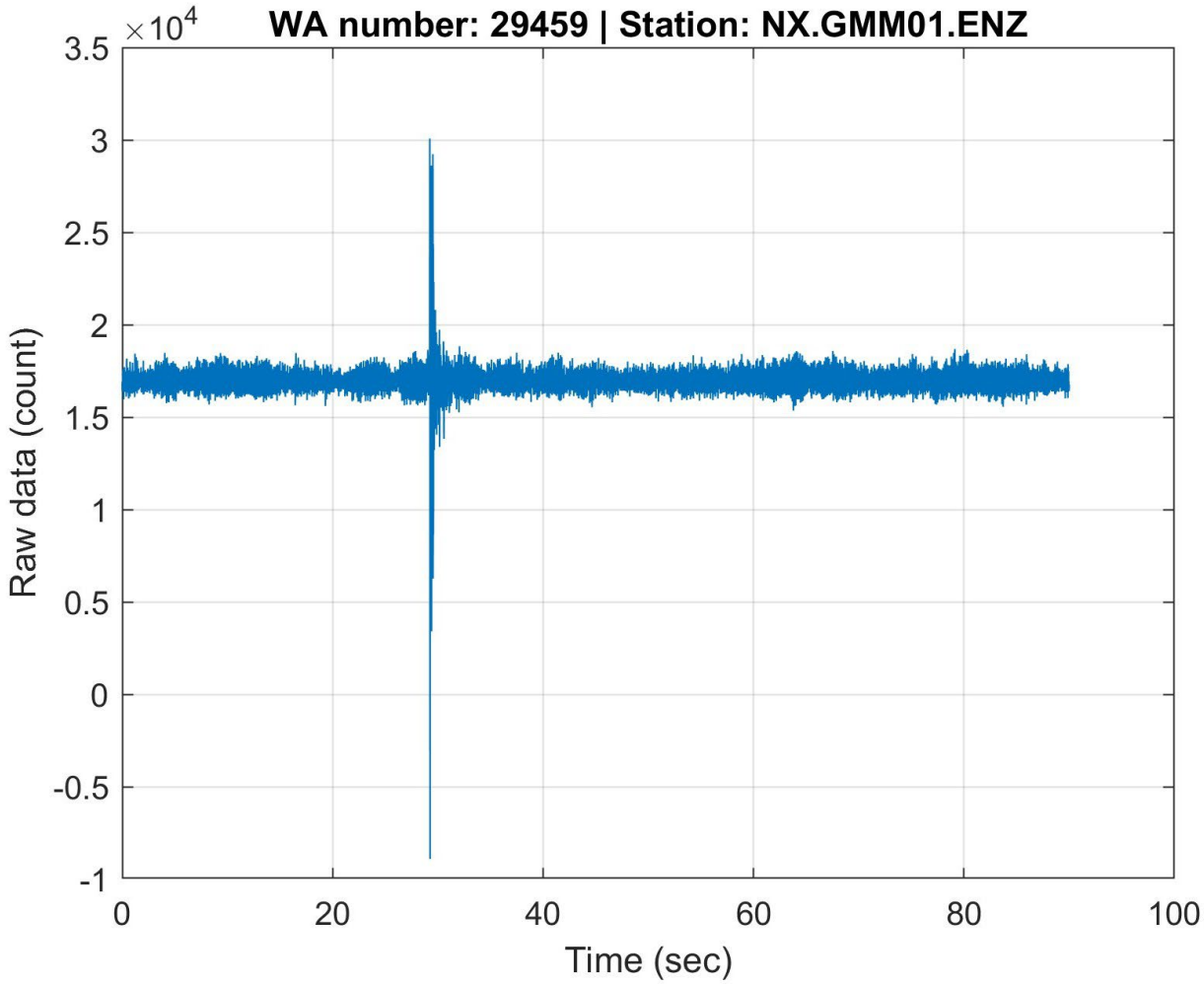

Figure C1. Example of a recorded waveform with earthquake signals visible within a relatively high background noise level. Although the onset of seismic phases can not be determined, ground motion amplitudes can be extracted from the waveform.

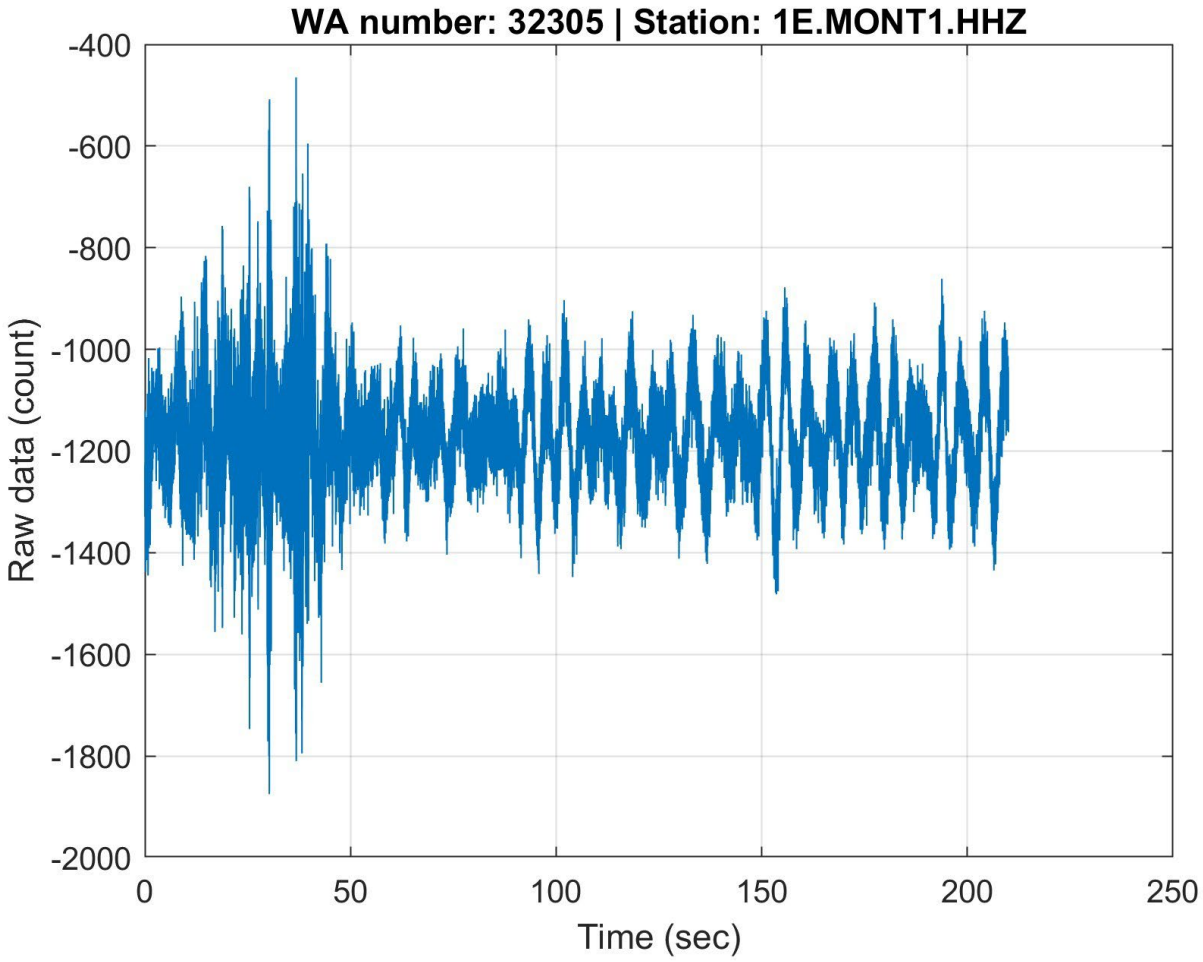

Figure C2. Example of a recorded waveform with earthquake signals within a very high background noise. The start of the earthquake signals (i.e., P waves) can not be determined but the peak ground motion amplitudes can be estimated.

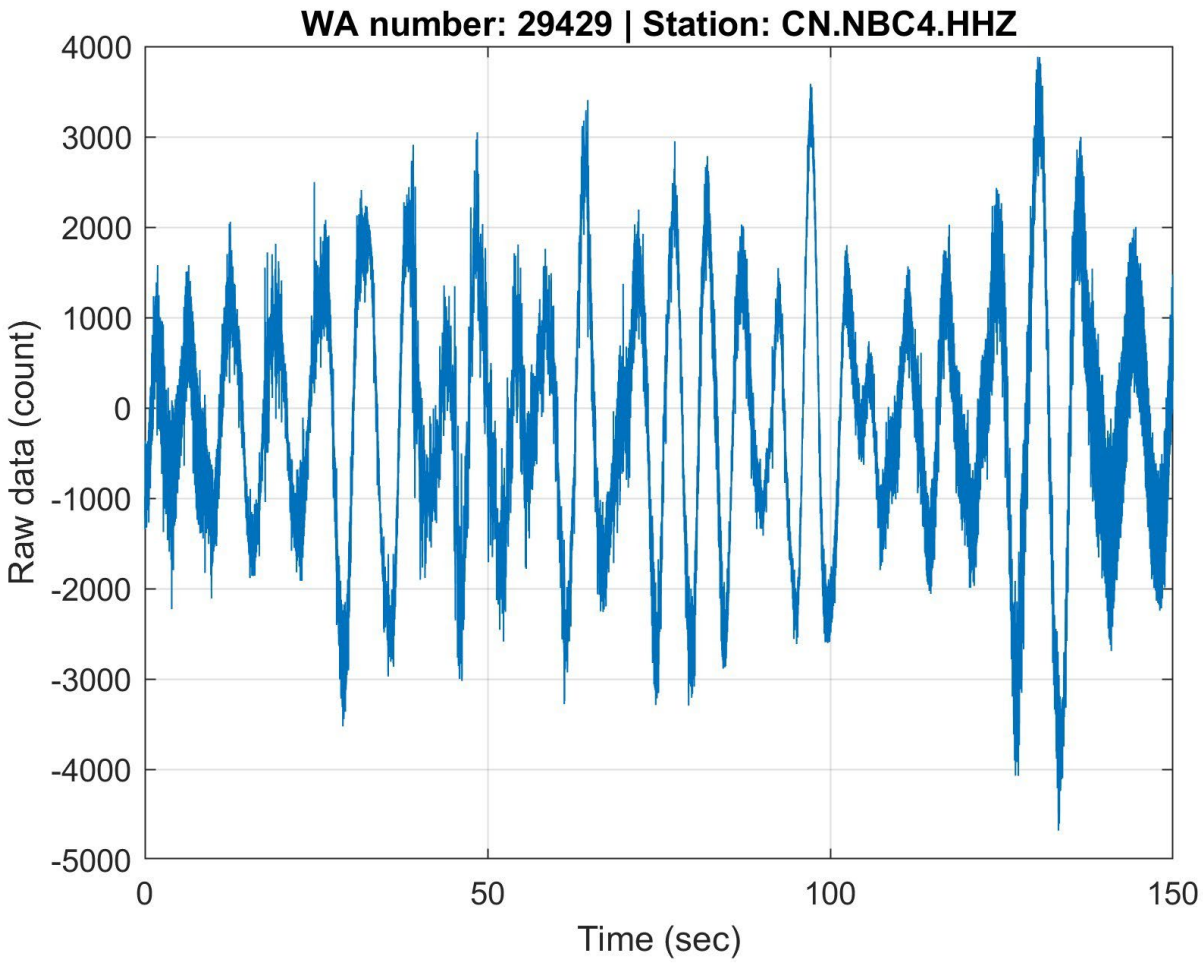

Figure C3. Example of a recorded waveform within earthquake signals buried completely within the very high background noise. This waveform can not be used for research without proper filtering to remove the long period noise from the time series.

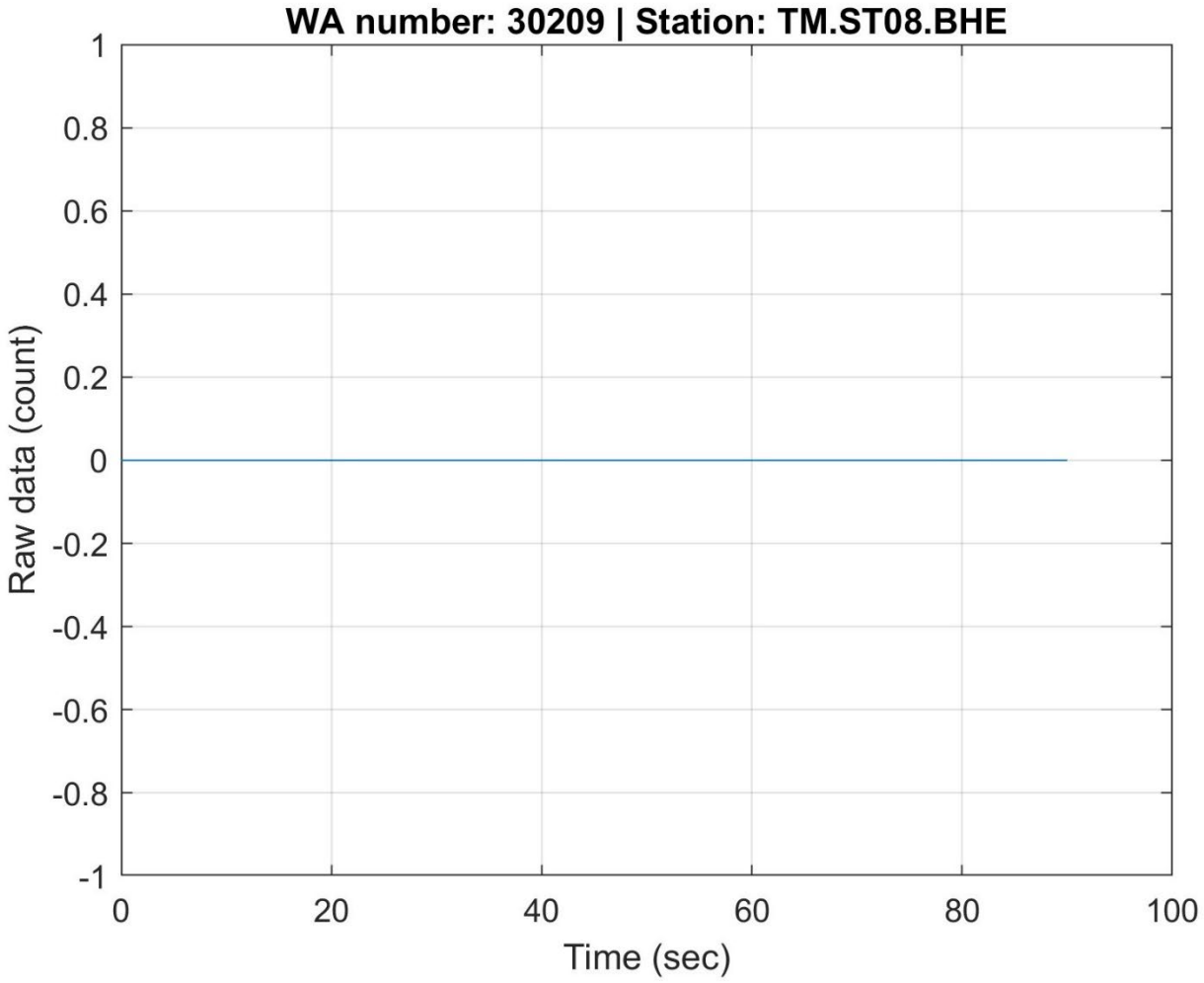

Figure C4. Example of a recorded waveform without any data possibly due to instrument glitch.