REPORT

Earthquake Acceleration Time History Development

for Broadway Subway Project, British Columbia

Submitted to:

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1.0 INTRODUCTION

This report presents site-specific earthquake acceleration response spectra and 35 sets of three-component, firm-ground acceleration time-histories developed by Golder Associates Inc. (Golder) for the Broadway Subway Project (BSP) in Vancouver, British Columbia, Canada. Microsoft Excel files with the spectrally-matched acceleration, velocity and displacement time-histories have been transmitted separate to this report. These response spectra and acceleration time-histories have been developed specifically to address the conditions and requirements of the BSP. They should not be used for other sites or projects without prior review and authorization by Golder. Furthermore, approaches to assessment of seismic hazards, available earthquake records, design codes and development of earthquake acceleration time-histories for design vary over time, such that updates would be appropriate if there is significant delay in implementation of detailed design beyond 2021.

1.1 Background

The BSP project comprises various structures, each of which has a different fundamental period. The project-wide period range of interest therefore varies from 0.01 to 10 seconds, although a majority of structures have relatively short fundamental periods at less than about one second.

1.2 Regulatory Standards

Golder understands that the structures within the BSP project will be designed in accordance with the seismic design provisions and criteria outlined in the CSA S6-14 Standard, Ministry of Transportation and Infrastructure (MoTI) Supplement to CSA S6-14 (2016), and the 2015 NBCC. CSA S6-14 includes recommendations for the development of earthquake acceleration time-histories used for seismic analysis. CSA S6-14 allows for both spectral-matching and linear-scaling methods for the development of acceleration time-histories. Analyses that use spectrally matched records generally provide an indication of the average seismic response of the structure. Linearly scaled records tend to provide an indication of the variability of the response of the structure over the different period ranges of interest.

The earthquake acceleration response spectra for the site were developed to be consistent with the requirements of the 2015 National Building Code of Canada (2015 NBCC). The earthquake acceleration time-histories were developed following the seismic design provisions in Canadian Highway Bridge Design Code (CHBDC CSA S6-14) Section 4.4.3.6: *Time-history Input Motions* and MoTI Supplement to CSA S6-14 (2016).

Because the periods of interest range from 0.01 to 10 seconds, two scenario spectra were considered as able to cover the short-period and long-period range of the project deisgn uniform hazard response spectra (UHRS).The envelop of the two scenario spectra is above 75% of the 2015 NBCC UHRS from 0.01 to 10 seconds. These scenario acceleration response spectra are consistent with the requirements in 2015 NBCC.

1.3 Scope of Work

Golder Associates Inc. (Golder) proposed an approach to develop earthquake acceleration response spectra and firm-ground earthquake acceleration time-histories for the BSP using data from the Geological Survey of Canada (GSC) Open-file 8090 Report published in 2016 (Halchuk et al. 2016). Golder's proposed approach was presented in an email communication with Stantec on May 3, 2018. The approach uses the spectral shape of the uniform hazard response spectra (UHRS) for individual types of sources, including crustal, inslab and interface sources (referred to as scenario UHRS hereafter), and scaled to the UHRS for all sources as provided in 2015 NBCC UHRS. The scenario UHRS for individual source types was obtained from Halchuk et al. (2016).

Golder's scope of work includes:

- Developing site-specific horizontal and vertical earthquake acceleration response spectra.
- Developing 10 suites of three-component acceleration time-histories for the 100-year and 475-year return period response spectra each with five records from crustal and five records from inslab earthquakes. Based on the results of de-aggregation for the 100-year and 475-year return periods obtained from Natural Resources Canada (NRCan), Golder does not consider it necessary to develop subduction interface response spectra and the associated time-histories for return periods of 100 and 475 years.
- Developing 15 suites of three-component acceleration time-histories for 2,475-year return period response spectrum with five records from crustal, five from interface, and five from inslab earthquakes.
- Prepare draft and final reports.

Thirty-five sets of three-component acceleration time-histories have been developed in total for three return periods: 100, 475 and 2,475 years. All acceleration response spectra are for a damping ratio of 5%.

1.4 Report Structure

This report describes the approach and result for the 35 sets of three-component acceleration time-histories developed for the three return periods: 100, 475 and 2,475 years.

This report has this introduction (Section 1.0) followed by:

- The seismic hazard results from NRCan and the development of the scenario earthquake spectra for the site (Section 2.0)
- The earthquake acceleration time-history development approach and methodology (Section 3.0)
- The earthquake acceleration time-history development results (Section 4.0)
- A summary of results (Section 5.0)
- References cited in the report (Section 6.0)
- Appendix A with spectral-matching result figures

1.5 Limitations

This report shall be read in conjunction with the "***Important Information and Limitations of This Report***" (Appendix B). This information is essential for the proper use and interpretation of this report.

2.0 EARTHQUAKE GROUND MOTIONS

The earthquake ground motion parameters for the site have been established using the 5th Generation Seismic Hazard Model and regional Seismogenic Source Zones developed by NRCan for use in the 2015 NBCC, as per Section 4.4.3.1 of CSA S6-14. The 5th Generation ground motion parameters for the site are available from the Interactive Website maintained by the NRCan for public use (http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php), but the de-aggregation results are not. Consequently, on 17 April 2018 Golder obtained the site-specific de-aggregation information directly from Dr. Halchuk of NRCan for return periods of 100, 475, and 2,475 years and for a set of spectral periods, including PGA, 0.2, 0.5 1.0 and 2.0 seconds. Golder has considered this data as “information that can be relied upon” for the development of earthquake scenario response spectra and the corresponding acceleration time-histories presented in this report.

2.1 Earthquake Hazard for the BSP Site

As noted above, the spectral acceleration (Sa) values and seismic hazard de-aggregation results for the BSP project were obtained from NRCan. The Sa values are those from the 5th Generation Seismic Hazard Model developed for the 2015 NBCC. The 5th Generation Seismic Hazard Model incorporates:

1) Seismic sources to represent the probability of occurrence of crustal, deep or inslab and interface Cascadia subduction zone earthquakes; and
2) Recently developed ground motion models (GMMs) for western Canada that estimate the attenuation of earthquake ground motions from the earthquake source to the site of interest.

NRCan makes the 2015 source model used to develop the seismic hazard maps available to the public (Geological Survey of Canada Open File #7576, Halchuk et al. 2014). NRCan also provides crustal, inslab and interface hazard values for southwestern Canada (GSC open file 8090, Halchuk et al. 2016). Halchuk et al. (2016) provide the UHRS spectral accelerations for more than 10,000 grid points with about 10-km spacing. The UHRS spectral accelerations at given grid points for crustal, inslab and interface sources were used to estimate Sa values at the site.

Table 1 lists 100-year, 475-year, and 2,475-year return period, 5%-damped spectral accelerations provided by NRCan for periods of 0.01 to 10 seconds for a 2015 NBCC soil Site Class C that has an average shear wave velocity in the upper 30 m soil layer, $V_{S,30}$, of 450 m/s. A 0.01 second period spectral acceleration is typically considered equal to the horizontal peak ground acceleration (PGA). The Sa values at each period listed in Table 1 have an equal probability of being exceeded and, therefore, these values define the shape of the UHRS.

Table 1: 5%-Damped Mean Spectral Acceleration Values for the 100-Year, 475-Year, and 2,475-Year Return Period (Site Class C)

Period (Seconds)	Mean Spectral Acceleration (g)		
	100-year	475-year	2,475-year
0.01 (PGA)	0.081	0.185	0.363
0.05	0.098	0.222	0.444
0.1	0.150	0.339	0.676
0.2	0.190	0.428	0.836
0.3	0.190	0.434	0.840
0.5	0.157	0.376	0.743
1	0.079	0.201	0.419
2	0.043	0.115	0.254
5	0.009	0.028	0.080
10	0.004	0.010	0.028

Seismic hazard de-aggregation results provided by NRCan are listed in Table 2 for the PGA and other selected spectral accelerations with a 100-year return period. Table 2 lists results for the mean and mode moment magnitude (**M**) and mean and mode source-to-site distance (R) that control the uniform hazard spectral acceleration values with a return period of 100 years. Table 3 and 4 list de-aggregation results for 475-year and 2,475-year return periods, respectively. Figures presenting the distribution of the contribution to hazard as a function of magnitude and distance were also provided by NRCan.

Table 2: De-aggregation Results from the 5th Generation Seismic Source Model: 100-Year Return Period (2015 NBCC)

Seismological Parameter	Controlling Earthquake	Magnitude (M)		Distance (km)	
		Mean	Mode	Mean	Mode
PGA	Crustal/Inslab	6.73	6.85	82	70
Sa (0.2s)	Crustal/Inslab	6.71	6.85	81	70
Sa (1s)	Inslab/Interface	7.12	6.85	113	70
Sa (2s)	Interface/Inslab	7.25	7.55	135	290
Sa (5s)	Interface	7.39	7.55	201	290
Sa (10s)	Interface	7.39	7.55	221	290

Table 3: De-aggregation Results from the 5th Generation Seismic Source Model: 475-Year Return Period (2015 NBCC)

Seismological Parameter	Controlling Earthquake	Magnitude (M)		Distance (km)	
		Mean	Mode	Mean	Mode
PGA	Crustal/Inslab	6.99	6.95	73	70
Sa (0.2s)	Crustal/Inslab	6.96	6.95	74	70
Sa (1s)	Inslab/Interface	7.54	8.95	98	150
Sa (2s)	Interface/Inslab	7.76	8.95	115	150
Sa (5s)	Interface	8.12	8.95	154	150
Sa (10s)	Interface	8.13	8.95	163	150

Table 4: De-aggregation Results from the 5th Generation Seismic Source Model: 2,475-Year Return Period (2015 NBCC)

Seismological Parameter	Controlling Earthquake	Magnitude (M)		Distance (km)	
		Mean	Mode	Mean	Mode
PGA	Crustal/Inslab	7.02	7.15	62	70
Sa (0.2s)	Crustal/Inslab	7.03	7.15	64	70
Sa (1s)	Inslab/Interface	7.79	8.95	94	150
Sa (2s)	Interface/Inslab	8.12	8.95	111	150
Sa (5s)	Interface	8.67	8.95	137	150
Sa (10s)	Interface	8.74	8.95	140	150

Golder's review of the percentage contribution to hazard plots (i.e. de-aggregation plots from NRCan) shows that at spectral periods shorter than 0.5 seconds, the hazard contributions are bimodal, with more hazard arising from large magnitude earthquakes (**M** >7.0) at distances greater than 50 km. The large-magnitude earthquakes are largely from the deep subduction inslab source zone labelled as "Georgia Strait/Puget Sound". There is also some hazard contribution from small to intermediate magnitude (**M**5.0 to **M**7.0) earthquakes at relatively short source-to-site distances of less than 40 km. Those moderate-magnitude and closer earthquakes are largely from the shallow crustal areal source zone labelled as "Vancouver Island Coast Mountains".

The 100-year, 475-year and 2,475-year return period hazards at a spectral period of 1.0 second is dominated by large-magnitude, subduction zone inslab and interface earthquakes (**M** >8.0) at source-to-site distances greater than 120 km. The large-magnitude earthquakes are attributed to the "Georgia Strait/Puget Sound" inslab and the distant Cascadia interface sources. For periods longer than 1.0 second, the subduction interface source earthquakes gradually increase their contribution to the total hazard, and the subduction interface source becomes the main contributor to the hazard at longer (> 2.0 seconds) spectral periods. These contributions to the hazard from the different earthquake types define the scenario earthquakes considered for the development of the acceleration time-histories in this study.

2.2 Periods of Interest

The BSP project comprises various structures, each of which has different fundamental periods. The project-wide period range of interest therefore varies from 0.01 to 10 seconds, although a majority of structures have relatively short fundamental periods of less than about one second.

2.3 Site-Specific Scenario Horizontal and Vertical Acceleration Response Spectra

The UHRS represents the envelope of expected earthquake ground motions from all contributing seismic sources across a period range from 0.01 to 10 seconds. The seismic hazard at the BSP site as discussed above, however, has contributions from multiple seismic sources, with the largest contributing source changing as the spectral period gets longer. Therefore, scenario response spectra following shapes of response spectra from the controlling earthquakes listed in Table 2 to Table 4 were considered as alternative target spectra for developing earthquake acceleration time-histories at the BSP site.

Golder used data from Halchuk et al. (2016) to develop scenario earthquake acceleration response spectra for the site. This method takes advantage of data developed by Geological Survey of Canada after the George Massey Tunnel Replacement (GMTR) project scenario spectra and acceleration time-histories were completed. Halchuk et al. (2016) provides scenario UHRS from crustal, inslab and interface seismic sources for selected return periods including 100, 475 and 2475 years. These scenario UHRS for individual source types were used as inputs to develop scenario spectra.

The scenario UHRS for individual source types at the site were interpolated from the UHRS at grid points in Halchuk et al. (2016). The four grid points closest to the site were identified; then their UHRS spectral acceleration values were read from Halchuk et al. (2016); weights were assigned to each UHRS proportional to the reciprocal of their distance to the site; and then the weighted average UHRS values were calculated and used as the UHRS at the site.

The scenario UHRS were scaled up to the UHRS for all sources. The scenario UHRS for crustal and inslab sources were scaled up to meet the UHRS at short periods, (<1.0 second); the scenario UHRS for interface sources were scaled up to meet the UHRS at long periods, (≥1.0 second). The envelop spectrum is required in 2015 NBCC Commentary J Annex 2.1.2 to be not lower than 75% of the UHRS at any periods. Figures 1 to 3 show the scenario UHRS for 100-year, 475-year, and 2,475-year return periods for the site. Note that the envelop spectrum falls below the UHRS from 2015 NBCC at periods from about 1 to 2 seconds. If the fundamental period of the structure of interest ranges from about 1 to 2 seconds, then the crustal/inslab or interface scenario UHRSs should be scaled up by about 10% to 30% to equal the 2015 NBCC UHRS at the fundamental period of interest (i.e., 1 to 2 seconds).

Period-dependent vertical-to-horizontal (V/H) spectral ratios were developed for the scenario earthquakes that contribute to the short- and long- period hazard at the GMTR project site using the Gülerce and Abrahamson (2011) method (Golder 2015). These V/H spectral ratios were considered applicable and were adopted in this study. The calculated scenario vertical acceleration response spectra are shown in the right subplots in Figure 1 to 3.

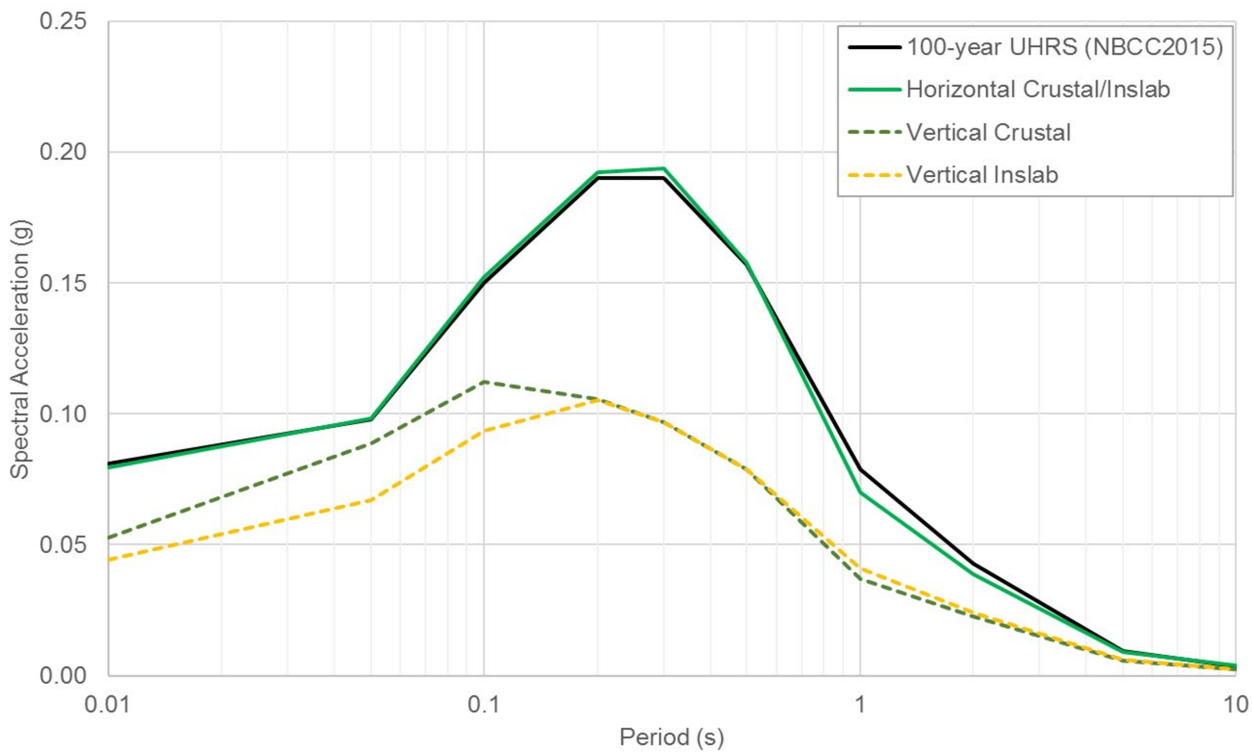

Figure 1: Horizontal and vertical target response spectra (5%-damped) for the 100-year return period and the 100-year return period horizontal UHRS.

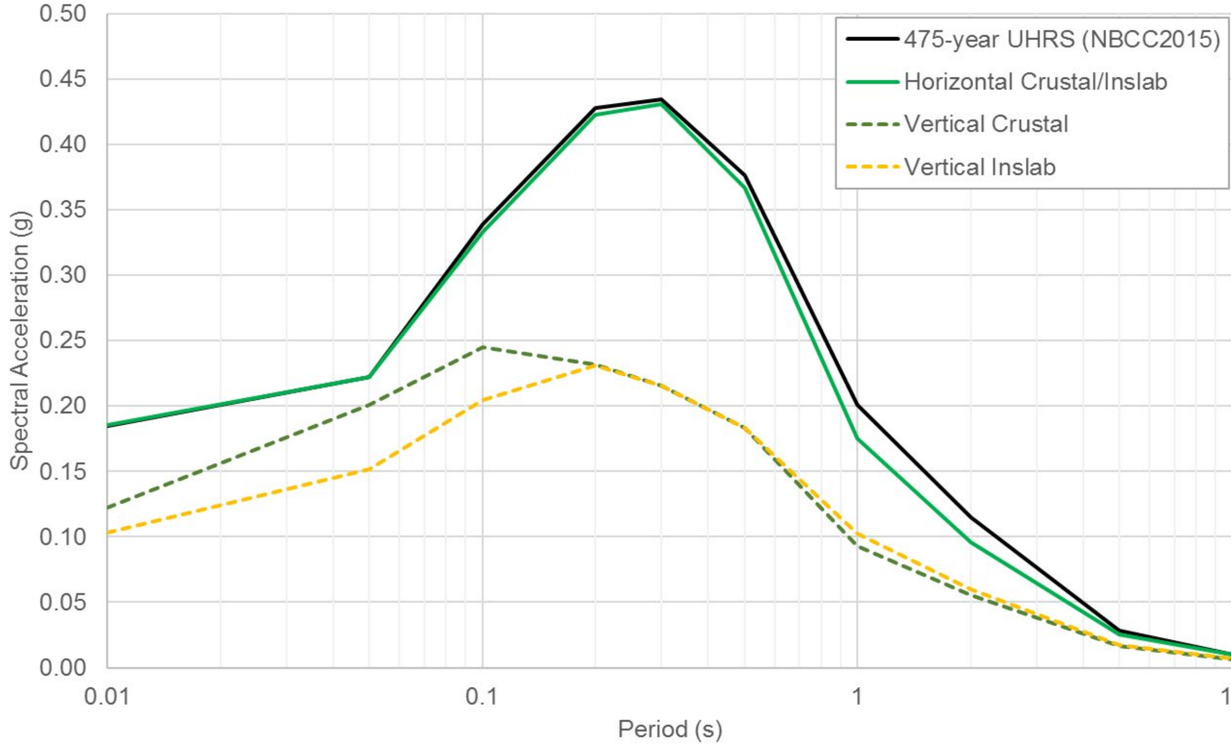

Figure 2: Horizontal and vertical target response spectra (5%-damped) for the 475-year return period and the 475-year return period horizontal UHRS.

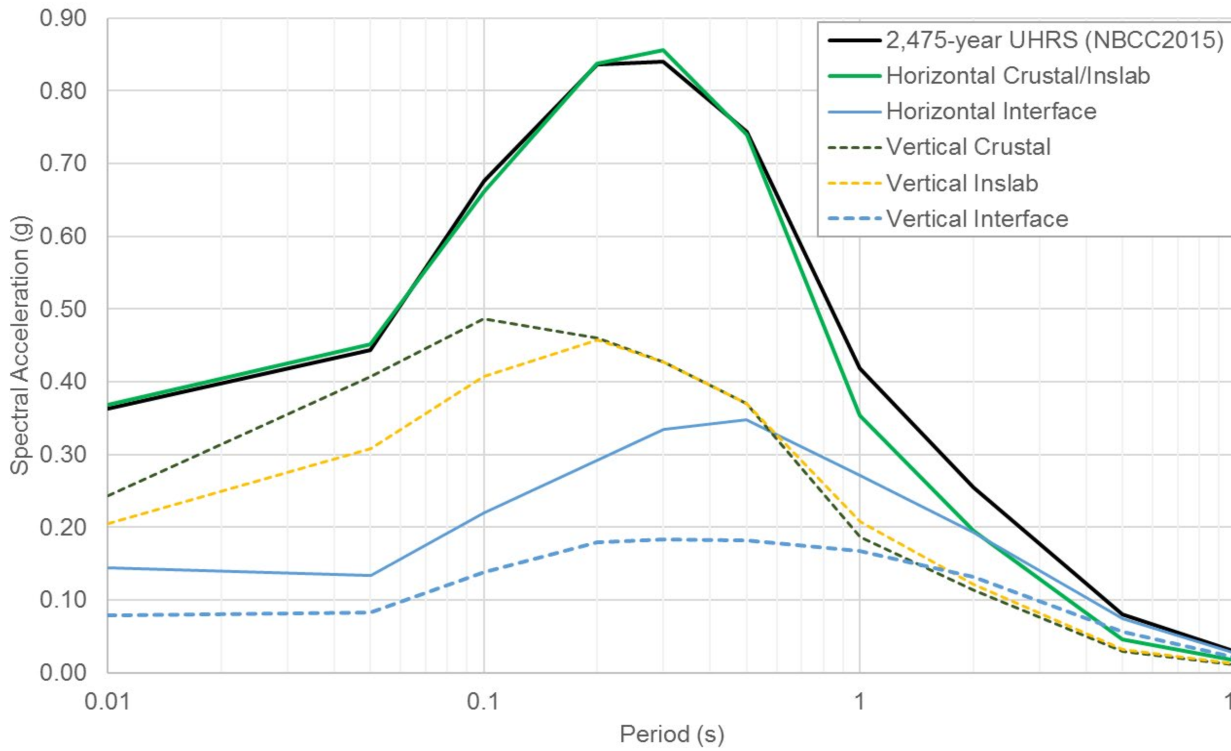

Figure 3: Horizontal and vertical target response spectra (5%-damped) for the 2,475-year return period and the 2,475-year return period horizontal UHRS.

Tables 5 to 7 list the spectral acceleration values for the scenario earthquake response spectra.

Table 5: 100-year Target Scenario Spectra for the Broadway Subway Project

Period (s)	Spectral Acceleration (g)		
	Horizontal Crustal/Inslab	Vertical Crustal	Vertical Inslab
0.01 (PGA)	0.080	0.053	0.044
0.05	0.098	0.089	0.067
0.1	0.152	0.112	0.094
0.2	0.192	0.106	0.105
0.3	0.194	0.097	0.097
0.5	0.158	0.079	0.079
1	0.070	0.034	0.041

Period (s)	Spectral Acceleration (g)		
	Horizontal Crustal/Inslab	Vertical Crustal	Vertical Inslab
2	0.039	0.023	0.024
5	0.009	0.006	0.006
10	0.004	0.002	0.003

Table 6: 475-year Target Scenario Spectra for the Broadway Subway Project

Period (s)	Spectral Acceleration (g)		
	Horizontal Crustal/Inslab	Vertical Crustal	Vertical Inslab
0.01 (PGA)	0.185	0.122	0.103
0.05	0.222	0.201	0.152
0.1	0.333	0.245	0.205
0.2	0.422	0.232	0.231
0.3	0.431	0.215	0.215
0.5	0.367	0.183	0.183
1	0.175	0.093	0.103
2	0.096	0.056	0.060
5	0.025	0.016	0.017
10	0.010	0.006	0.007

Table 7: 2,475-year Target Scenario Spectra for the Broadway Subway Project

Period (s)	Spectral Acceleration (g)				
	Horizontal Crustal/Inslab	Vertical Crustal	Vertical Inslab	Horizontal Interface	Vertical Interface
0.01 (PGA)	0.368	0.243	0.205	0.144	0.078
0.05	0.451	0.407	0.308	0.134	0.083
0.1	0.661	0.486	0.406	0.219	0.138

Period (s)	Spectral Acceleration (g)				
	Horizontal Crustal/Inslab	Vertical Crustal	Vertical Inslab	Horizontal Interface	Vertical Interface
0.2	0.837	0.460	0.458	0.292	0.179
0.3	0.855	0.428	0.428	0.335	0.183
0.5	0.739	0.370	0.370	0.348	0.181
1	0.354	0.187	0.207	0.271	0.168
2	0.195	0.113	0.122	0.193	0.131
5	0.046	0.029	0.032	0.074	0.056
10	0.017	0.011	0.012	0.027	0.020

3.0 TIME-HISTORY DEVELOPMENT

This section describes the methods used to develop the acceleration time-histories, including spectral matching process and the selection of recorded earthquake strong motion for spectral matching.

3.1 Spectral Matching Process

The process of modifying an earthquake strong motion record or seed earthquake motion so that it closely matches a target acceleration response spectrum is known as “spectral matching”. The objective of spectral matching is to reduce the individual spectral peaks and troughs of the seed acceleration time-history while closely preserving its non-stationary characteristics (e.g., Abrahamson 1992).

Spectral matching for this study used the time-domain matching method as developed by Lilhanand and Tseng (1988) and modified by Abrahamson (1992), Hancock et al. (2006), and Al Atik and Abrahamson (2010). Time-domain spectral matching adds wavelets in the time domain to improve the spectral deficiencies of the seed motion so that its response spectrum better matches the target acceleration response spectrum. The wavelets introduce less energy into the acceleration time-history than adjusting time-histories in the frequency domain and preserve the non-stationary characteristics of the seed acceleration time-history (Hancock et al. 2006). Typically, several iterations are required to obtain reasonable convergence between the spectrally matched acceleration time-history and the target response spectrum. A final baseline correction is often necessary to remove any permanent offset on the displacement time-history introduced during the spectral matching procedure.

Spectral matching for this study used the computer program RSPMatch09 developed by Al Atik and Abrahamson (2010) and published by Fouad and Rathje (2012).

To provide a better spectral match across the wide period range from 0.01 to 10 seconds, a smaller period range for spectral matching was used in this study, with different period ranges targeted to each source type. For example, crustal and inslab records were matched for a target period range of 0.02 to 5 seconds for shorter spectral periods, while interface records were matched for a target period range of 0.05 to 10 seconds to capture better the longer period strong ground motions.

3.2 Selection of Seed Acceleration Time-Histories

3.2.1 General

Seed earthquake acceleration time-histories are typically selected based on the earthquake magnitude and source-to-site distance ranges that represent the earthquake scenarios that contribute most to the total seismic hazard. These magnitudes and distances are selected for the return period and structural period of interest by de-aggregation analysis of the PSHA.

Once the scenario earthquakes are selected, recorded earthquake acceleration time-histories are selected that have similar source, path, and site properties to the scenario earthquakes evaluated from the de-aggregation analysis. The time-history selection criteria generally include earthquake magnitude, source-to-site distance, style of faulting, rupture directivity, and near-surface ground condition at the recording station.

Bommer and Acevedo (2004) and Abrahamson (2011) suggest that in selecting acceleration time-histories for spectral matching, the key earthquake parameters that will affect the non-stationary character of the waveform are earthquake magnitude and source-to-site distance. For earthquake magnitude, the recordings should ideally be within a 0.5 magnitude unit of the selected design earthquake (e.g., mean earthquake magnitude from de-aggregation results). For source-to-site distance selection, the proximity to the seismic source is very important. For example, records from sites located within about 10 km of an active fault, the near-field effects (e.g., directivity velocity pulse) in the ground shaking triggered by earthquakes on the fault can be a significant contribution to the record. Earthquake acceleration time-histories with these velocity pulses may need to be included or excluded, depending on the sites’ location with respect to known active faults. If multiple recordings are used, they should be selected so that they have a range of non-stationary characteristics from various motions induced by multiple earthquakes.

Abrahamson (2011) argues that finding an acceleration record with the same style of faulting (e.g., normal, reverse, and strike-slip) as the selected design earthquake is not important. Similarly, the subsurface ground condition of the recorded seed records is also less relevant in spectral matching because the spectral matching process corrects for differences in frequency content between the ground condition of the seed records and the ground conditions of the target acceleration response spectrum (Al Atik and Abrahamson 2010).

3.2.2 Selection of Time-Histories for BSP

Fifteen sets of acceleration time-histories were selected and scaled to the 2,475-year return period horizontal and vertical scenario acceleration response spectra for use as input in the dynamic analysis of the BSP. Ten sets were selected and scaled to the 475-year and 100-year return period spectra. CSA S6-14 Section 4.4.3.6 provides guidance for the selection and modification of recorded earthquake ground motion acceleration time-histories for use in the dynamic analysis of bridges. Section 4.4.3.6 specifies that the selected motions should be representative of the tectonic environment, earthquake magnitude, source to site distance and local soil conditions. Additional selection criteria and considerations used in this study are as follows:

- Similarity of the overall shape of the response spectrum from the seed record and the geometric mean of two horizontal components relative to the target spectrum.
- Selection of seed records based on the earthquake source mechanism.
- Selection of seed records with scaling factors less than four for individual horizontal and vertical components.

Five sets of earthquake acceleration recordings were selected to represent earthquake ground motions associated with each type of seismic source. Records were selected to represent the small- to large-magnitude shallow crustal earthquakes and large-magnitude earthquakes from both the Cascadia subduction interface source and the Georgia Strait/Puget Sound subduction inslab seismic source. Very few subduction inslab and interface earthquake strong motion recordings are available worldwide, especially recordings with compatible spectral shapes to the target spectra for the BSP site. Acceleration time-histories were selected from the following earthquakes:

- 1999 **M**7.1 Hector Mine crustal earthquake
- 1992 **M**7.3 Landers crustal earthquake
- 1986 **M**7.3 Taiwan crustal earthquake
- 1999 **M**7.6 Taiwan crustal earthquake
- 2001 **M**7.6 El Salvador inslab earthquake
- 2001 **M**6.8 Nisqually inslab earthquake
- 2005 **M**7.8Tarapaca Chile inslab earthquake
- 2005 **M**7.2 Miyagi-Oki, Japan inslab earthquake
- 2003 **M**8.0 Tokachioki, Japan subduction interface earthquake
- 2011 **M**9.0 Tohoku, Japan subduction interface earthquake

The acceleration time-histories were obtained from the PEER, Consortium of Organizations for Strong-Motion Observations Systems (COSMOS), University of Chile, and S2GM® tool databases. Ten out of 15 seed acceleration time-histories were adopted from the GMTR project. Five out of 15 seed acceleration time-histories from the GMTR project were replaced with seed acceleration time-histories whose spectral shapes are closer to the target spectra for BSP. The same set of seed records for each earthquake mechanism was used for all return periods of interest. Tables 8 through 10 list key parameters for the selected acceleration time-histories.

Table 8: Parameters for Acceleration Time-Histories Selected for the Crustal Earthquake Scenario

RSN[1]	Earthquake Name	Year	Station	Magnitude (M)	R_{rup}[2] (km)	Time Step (s)	Total Duration (s)
580	Taiwan SMART1	1986	SMART1 006	7.3	54	0.01	48.5
1282	Chi-Chi, Taiwan	1999	HWA033	7.6	53	0.005	73.5
1292	Chi-Chi, Taiwan	1999	HWA045	7.6	63	0.004	70.1

RSN[1]	Earthquake Name	Year	Station	Magnitude (M)	R_{rup}[2] (km)	Time Step (s)	Total Duration (s)
1794	Hector Mine	1999	Joshua Tree	7.1	31	0.005	40.1
3756	Landers	1992	Morongo Valley Hall (GEOS #58)	7.3	41	0.005	56.4

Notes:
1. RSN = Record sequence number; Number assigned by PEER database to each individual record.
2. R_{rup} = Closest distance to rupture.

Table 9: Parameters for Acceleration Time-Histories Selected for the Inslab Earthquake Scenario

Earthquake Name	Year	Station	Magnitude (M)	R_{rup}[1] (km)	Time Step (s)	Total Duration (s)
El Salvador	2001	DB	7.6	110	0.005	44.5
El Salvador	2001	RF	7.6	113	0.005	61.3
Miyagi	2005	MYG006	7.2	110	0.01	50.2
Nisqually	2001	7032-1416	6.8	75	0.005	57.5
Tarapaca	2005	Iquique IDIEM	7.8	-	0.005	55.8

Notes:
1. R_{rup} = Closest distance to rupture. Distance for Tarapaca event is unknown.

Table 10: Parameters for Acceleration Time-Histories Selected for the Interface Earthquake Scenario

Earthquake Name	Year	Station	Magnitude (M)	R_{rup}[1] (km)	Time Step (s)	Total Duration (s)
Tohoku, Japan	2011	CHB026	9.0	185	0.01	254.6
Tohoku, Japan	2011	KNG003	9.0	228	0.01	208.0
Tokachioki, Japan	2003	HKD107	8.0	148	0.01	97.7
Tokachioki, Japan	2003	HKD105	8.0	184	0.01	85.0
Tokachioki, Japan	2003	HKD181	8.0	241	0.01	717.5

Notes:
1. R_{rup} = Closest distance to rupture.

4.0 TIME-HISTORY DEVELOPMENT RESULTS

The selected earthquake ground motions were spectrally-matched to meet the following criteria:

- The matched response spectrum agrees reasonably well with the target spectrum.
- The non-stationary characteristics of the initial time series are well maintained.
- The Fourier amplitude spectrum has not been changed significantly.
- The Arias intensity agrees reasonably well with that for the initial time-histories.
- The mean of the spectrally-matched acceleration time-histories do not fall more than 10% below the target at any one frequency.

Figures A1 to A17 show the spectral matching results for the crustal seed records and for the 100-year return period target scenario spectra for the horizontal and vertical components shown in Figure 1. As seen in these figures, the spectrally-matched motions have an acceleration response spectrum that closely matches the design acceleration response spectrum.

The spectrally matched acceleration, velocity and displacement time-histories are compared with the initial seed acceleration, velocity and displacement time-histories in Figures A3 to A17. These figures also show the target, initial and spectrally-matched acceleration response spectra, Fourier amplitude spectra for the initial and spectrally-matched acceleration time-histories and the normalized Arias intensity for the initial and spectrally-matched acceleration time-histories. The initial acceleration response spectrum has been scaled using the scale factor used in spectral matching.

Because the solution in spectral matching is not unique (i.e., there are an infinite number of motions that will produce the target spectrum), the acceleration, velocity and displacement time-histories were reviewed to confirm that the non-stationary characteristics of the initial time series have been maintained.

Zero-padding at the beginning of the initial time series was required in some cases for crustal and inslab earthquake records when the matching process was applied at Sa with longer periods (>5 s). Padding the beginning of an acceleration time series eliminates any drift in the resulting velocity and displacement time-histories. Al Atik and Abrahamson (2010) have shown that this approach preserves the non-stationary characteristics of the initial time-history. This approach in spectral matching has been implemented in the latest version of RspMatch09 and ensures convergence and stability of the spectral matching solution. The same zero-padding was applied to all three components in the same suite of records.

Earthquake ground motions were spectrally matched to the 100-year return period target scenario spectra for inslab earthquake records as shown in Figures A18 to A34. Ground motions matched to the 475-year return period are shown in Figures A35 to A68. Ground motions matched to the 2,475-year return period are shown in Figures A69 to A85, A86 to A102, and A103 to A119 for crustal, inslab and interface earthquake records respectively.

The main parameters for the spectrally-matched acceleration time-histories associated with 100-year return period are listed in Table 11 for the horizontal components. Tables 12 and 13 list the parameters for the horizontal components associated with 475- and 2,475-year return periods. Similarly, Tables 14, 15 and 16 list the main parameters for the spectrally matched, vertical acceleration time-histories associated with 100-year, 475-year, and 2,475-year return periods.

Table 11: Key Intensity Parameters for Horizontal Acceleration Time-Histories Matched for the 100-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	SD_{5-95}[1] (s)	Arias Intensity (m/s)	CAV[2] (m/s)	PGV[3] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	EW	0.5	21.9	0.10	3.4	6.8
			NS	0.5	18.7	0.07	2.9	7.5
	Chi-Chi, Taiwan	HWA003	E	0.5	20.7	0.10	3.8	6.0
			N	0.5	19.5	0.08	3.1	5.7
	Chi-Chi, Taiwan	HWA045	N	0.5	12.9	0.07	2.5	9.2
			W	0.7	21.4	0.09	3.4	8.0
	Hector Mine	Joshua Tree	090	0.6	13.7	0.09	2.9	8.4
			360	0.5	15.6	0.08	2.8	9.3
	Landers	Morongo Valley Hall (GEO #58)	000	0.5	32.9	0.14	5.0	5.6
			090	0.6	34.5	0.23	6.6	6.2
Inslab	El Salvador	DB	180	0.4	24.9	0.16	4.7	7.5
			270	0.4	25.2	0.12	4.0	6.4
	El Salvador	RF	180	0.4	24.3	0.10	3.7	6.5
			90	0.4	22.7	0.10	3.7	6.8
	Miyagi	MYG006	EW	0.4	28.9	0.11	4.1	6.1
			NS	0.5	27.8	0.15	4.8	7.1
	Nisqually	7032-1416	125	0.6	24.0	0.09	3.2	5.9
			215	0.6	28.9	0.10	3.6	6.6
	Tarapaca	IQUIQUE IDIEM	L	0.5	25.0	0.16	4.9	7.0
			T	0.4	17.7	0.07	2.9	8.0

Notes:
1. SD_{5-95} = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Table 12: Key Intensity Parameters for Horizontal Acceleration Time-Histories Matched for the 475-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	$SD_{5\text{-}95}$[1] (s)	Arias Intensity (m/s)	CAV[2] (m/s)	PGV[3] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	EW	1.2	23.9	0.6	8.6	18.2
			NS	1.1	18.8	0.4	7.0	16.5
	Chi-Chi, Taiwan	HWA003	E	1.1	18.2	0.5	8.1	18.3
			N	1.2	16.5	0.4	6.4	15.6
	Chi-Chi, Taiwan	HWA045	N	1.1	12.2	0.3	5.4	18.0
			W	1.5	21.5	0.5	7.7	20.2
	Hector Mine	Joshua Tree	090	1.4	13.8	0.5	6.6	20.2
			360	1.1	13.6	0.4	5.6	23.3
	Landers	Morongo Valley Hall (GEO #58)	000	1.0	32.8	0.8	11.9	15.4
			090	1.4	34.6	1.2	15.3	16.0
Inslab	El Salvador	DB	180	0.9	24.8	0.8	10.6	15.2
			270	1.0	23.3	0.5	7.9	15.0
	El Salvador	RF	180	1.0	24.3	0.6	8.6	17.4
			90	1.0	22.3	0.5	8.1	15.6
	Miyagi	MYG006	EW	1.0	29.2	0.7	10.4	13.3
			NS	1.2	27.2	0.8	10.5	13.6
	Nisqually	7032-1416	125	1.5	30.0	0.7	10.6	18.0
			215	1.4	28.9	0.5	8.2	18.0
	Tarapaca	IQUIQUE IDIEM	L	1.0	22.3	0.6	9.4	16.8
			T	1.0	20.7	0.6	8.8	21.8

Notes:
1. $SD_{5\text{-}95}$ = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Table 13: Key intensity Parameters for Horizontal Acceleration Time-Histories Matched for the 2,475-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	$SD_{5\text{-}95}$[2] (s)	Arias Intensity (m/s)	CAV[3] (m/s)	PGV[4] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	EW	2.3	24.0	2.6	18.7	35.0
			NS	2.1	18.3	1.6	13.8	30.7
	Chi-Chi, Taiwan	HWA003	E	2.4	20.4	2.2	17.7	34.9
			N	2.4	16.9	1.5	13.0	28.2
	Chi-Chi, Taiwan	HWA045	N	2.1	12.1	1.2	10.4	40.2
			W	3.1	22.0	1.9	15.7	40.2
	Hector Mine	Joshua Tree	090	2.7	13.7	1.9	13.2	40.6
			360	2.1	14.1	1.5	11.5	47.0
	Landers	Morongo Valley Hall (GEO #58)	000	2.1	32.3	3.3	24.0	29.5
			090	2.8	34.5	4.9	30.4	28.6
Inslab	El Salvador	DB	180	1.8	24.7	3.3	21.4	30.7
			270	1.8	24.1	2.2	17.2	34.0
	El Salvador	RF	180	1.9	24.2	2.2	17.2	34.8
			90	1.9	22.1	1.8	15.6	28.0
	Miyagi	MYG006	EW	2.1	28.9	2.8	20.9	27.6
			NS	2.4	27.3	3.0	21.2	34.6
	Nisqually	7032-1416	125	2.6	21.9	1.8	14.3	31.2
			215	2.9	28.9	2.1	16.3	34.1
	Tarapaca	IQUIQUE IDIEM	L	2.0	21.0	2.3	17.2	32.3
			T	2.0	19.5	2.2	16.6	47.1
Interface	Tohoku, Japan	CHB026	EW	1.9	114.3	1.5	28.4	23.2
			NS	1.9	72.2	0.9	18.7	26.7

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	SD_{5-95}[2] (s)	Arias Intensity (m/s)	CAV[3] (m/s)	PGV[4] (cm/s)
	Tohoku, Japan	KNG003	EW	2.7	67.2	0.6	13.8	39.1
			NS	2.8	80.7	0.8	16.6	22.8
	Tokachioki, Japan	HKD107	EW	2.0	50.1	1.1	17.2	36.9
			NS	2.4	47.1	1.1	16.4	30.3
	Tokachioki, Japan	HKD105	EW	1.1	33.0	0.8	11.9	35.4
			NS	1.1	37.4	0.7	11.3	29.6
	Tokachioki, Japan	HKD181	EW	2.2	78.3	1.4	24.4	31.6
			NS	1.8	81.9	1.5	24.7	31.4

Notes:
1. SD_{5-95} = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Table 14: Key Intensity Parameters for Vertical Acceleration Time-Histories Matched for the 100-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	SD_{5-95}[1] (s)	Arias Intensity (m/s)	CAV[2] (m/s)	PGV[3] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	DN	0.6	20.4	0.04	2.2	3.6
	Chi-Chi, Taiwan	HWA033	V	0.7	26.9	0.04	2.5	4.4
	Chi-Chi, Taiwan	HWA045	V	0.6	21.6	0.03	2.1	4.6
	Hector Mine	Joshua Tree	UP	0.3	17.6	0.04	1.9	3.5
	Landers	Morongo Valley Hall (GEOS #58)	UP	0.3	29.9	0.07	3.3	3.4
Inslab	El Salvador	DB	UP	0.3	26.6	0.06	3.0	5.0
	El Salvador	RF	UP	0.4	25.1	0.05	2.8	5.3

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	$SD_{5\text{-}95}$[1] (s)	Arias Intensity (m/s)	CAV[2] (m/s)	PGV[3] (cm/s)
	Miyagi	MYG006	UD	0.5	30.4	0.07	3.4	2.8
	Nisqually	7032-1416	UP	0.6	31.1	0.05	2.8	3.5
	Tarapaca	IQUIQUE IDIEM	V	0.5	29.9	0.06	3.2	4.4

Notes:
1. $SD_{5\text{-}95}$ = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Table 15: Key Intensity Parameters for Vertical Acceleration Time-Histories Matched for the 475-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	$SD_{5\text{-}95}$[1] (s)	Arias Intensity (m/s)	CAV[2] (m/s)	PGV[3] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	DN	1.4	20.5	0.2	5.2	9.5
	Chi-Chi, Taiwan	HWA033	V	1.7	27.6	0.2	6.1	10.5
	Chi-Chi, Taiwan	HWA045	V	1.5	24.7	0.2	4.7	11.0
	Hector Mine	Joshua Tree	UP	0.9	18.1	0.2	5.0	10.7
	Landers	Morongo Valley Hall (GEOS #58)	UP	0.8	30.4	0.4	7.6	9.0
Inslab	El Salvador	DB	UP	0.8	26.8	0.3	6.7	12.0
	El Salvador	RF	UP	0.8	24.5	0.2	6.1	11.0
	Miyagi	MYG006	UD	1.2	29.0	0.3	6.6	7.7
	Nisqually	7032-1416	UP	1.4	31.4	0.3	6.4	9.8
	Tarapaca	IQUIQUE IDIEM	V	1.1	30.1	0.3	7.6	11.1

Notes:
1. $SD_{5\text{-}95}$ = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Table 16: Key Intensity Parameters for Vertical Acceleration Time-Histories Matched for the 2,475-year Return Period

Earthquake Scenario	Earthquake Name	Station	Component	Scale Factor	SD_{5-95}[2] (s)	Arias Intensity (m/s)	CAV[3] (m/s)	PGV[4] (cm/s)
Crustal	Taiwan SMART1	SMART1 006	DN	2.9	20.5	0.9	10.6	18.5
	Chi-Chi, Taiwan	HWA033	V	3.4	28.0	0.9	12.1	20.9
	Chi-Chi, Taiwan	HWA045	V	2.9	21.4	0.6	8.8	22.9
	Hector Mine	Joshua Tree	UP	1.8	16.8	0.7	8.4	19.8
	Landers	Morongo Valley Hall (GEOS #58)	UP	1.6	30.5	1.4	15.0	16.8
Inslab	El Salvador	DB	UP	1.5	27.1	1.3	14.0	25.5
	El Salvador	RF	UP	1.5	25.1	1.0	12.0	19.4
	Miyagi	MYG006	UD	2.3	28.6	1.1	13.0	18.8
	Nisqually	7032-1416	UP	2.8	31.1	1.1	12.9	19.6
	Tarapaca	IQUIQUE IDIEM	V	2.1	30.5	1.4	15.8	18.9
Interface	Tohoku, Japan	CHB026	UD	2.1	82.8	0.4	11.1	15.8
	Tohoku, Japan	KNG003	UD	3.5	77.8	0.3	9.9	15.7
	Tokachioki, Japan	HKD107	UD	2.4	56.8	0.4	10.5	21.0
	Tokachioki, Japan	HKD105	UD	1.8	60.9	0.5	11.8	19.3
	Tokachioki, Japan	HKD181	UD	2.2	78.9	0.4	11.0	20.4

Notes:
1. SD_{5-95} = Significant duration; the time between 5% and 95% of the total energy.
2. CAV = Cumulative absolute velocity.
3. PGV = Peak ground velocity.

Earthquake magnitude and distance are causal parameters that are only an indirect measure of the source and travel path characteristics of the selected time-histories. Direct measures of the intensity of the spectrally matched earthquake acceleration time-histories, including significant durations, AI and PGV were further compared to predictions of these intensity measured using the empirical relations listed in Tables 17 to 18.

Table 17: Predicted Significant Durations for Scenario Earthquakes Using Empirical Relations

Earthquake Scenario	Intensity Measure	Empirical Equation	Median	16th Percentile	84th Percentile
Crustal (**M**7.0 @ 30km)	Horizontal $SD_{5\text{-}95}$ (s)	Abrahamson and Silva (1996)	19	12	31
	Vertical $SD_{5\text{-}95}$ (s)	Abrahamson and Silva (1996)	17	11	27
Inslab (**M**7.15 @ 70km)	Horizontal $SD_{5\text{-}95}$ (s)	Abrahamson and Silva (1996)	27	16	43
	Vertical $SD_{5\text{-}95}$ (s)	Abrahamson and Silva (1996)	27	17	42
Interface (**M**8.95 @ 150km)	Horizontal $SD_{5\text{-}95}$ (s)	Abrahamson and Silva (1996)[1]	96	59	157

The AI values listed in Table 18 have been scaled to represent the given earthquake scenario. The target spectrum for spectral matching is not the median response spectrum for the given earthquake scenario, but rather the UHRS. Therefore, to obtain the AI for the target scenario, it is necessary to scale the empirically predicted AI (for median response spectra) by a scale factor equal to the square of the ratio of PGA for the UHRS and median spectrum. For example, the 2,475-year PGA of the UHRS is about 1.37 times the median spectral acceleration predicted using Abrahamson et al. (2016) ground motion model for the inslab earthquake scenario. A scale factor of 1.9 (~=1.37^2) is, therefore, applied to the AI values predicted using the empirical relation in Bullock et al. (2017) in Table 18. PGA values were calculated using the ground motion model of Abrahamson et al. (2016) for interface and inslab scenarios, while the ground motion model of Abrahamson et al. (2014) was used for the crustal scenario.

Table 18: Predicted Arias Intensity Measures (in m/s) for Scenario Earthquakes Using Empirical Relations

Return Period (year)	Earthquake Scenario	Empirical Equation	Median	16th Percentile	84th Percentile	Scale Factor
100	Crustal (**M**7.0 @ 30km)	Travasarou et al. (2002)	0.11	0.04	0.33	0.4
		Bullock et al. (2017)	0.12	0.04	0.36	
	Inslab (**M**7.15 @ 70km)	Bullock et al. (2017)	0.05	0.02	0.12	0.2
475	Crustal (**M**7.0 @ 30km)	Travasarou et al. (2002)	0.59	0.20	1.8	2.2
		Bullock et al. (2017)	0.64	0.22	1.9	
	Inslab (**M**7.15 @ 70km)	Bullock et al. (2017)	0.26	0.10	0.63	1.0

Return Period (year)	Earthquake Scenario	Empirical Equation	Median	16^{th} Percentile	84^{th} Percentile	Scale Factor
2,475	Crustal (**M**7.0 @ 30km)	Travasarou et al. (2002)	2.3	0.78	7.0	8.7
		Bullock et al. (2017)	2.5	0.87	7.5	
	Inslab (**M**7.15 @ 70km)	Bullock et al. (2017)	1.0	0.41	2.5	4.1
	Interface (**M**8.95 @ 150km)	Bullock et al. (2017)	0.7	0.29	1.7	1.9
		Foulser-Piggott and Goda (2015) for Japan	1.4	0.34	5.4	

Comparison of the intensity measures for the spectrally-matched time-histories (Tables 11 to 16) to predicted intensity measures for the given earthquake scenarios (Tables 17 and 18) indicates that:

- Overall, the SD_{5-95} of spectrally-matched motions in Tables 11 to16 are mostly within the 16^{th} and 84^{th} percentiles of the predicted values listed in Tables 17. The AI of spectrally-matched time-histories in Tables 11 to 13 are mostly within 16th and 84th percentiles of predicted values in Table 18.
- For the SD_{5-95} intensity parameter
  - For subduction interface acceleration time-histories, the SD_{5-95} predicted from the relation of Abrahamson and Silva (1996) ranges from about 59 to 157 seconds. The Tohoku earthquake motions tend to have longer durations, while the Tokachioki motions have shorter durations because of its relatively lower earthquake magnitude.
  - For inslab time-histories, the SD_{5-95} values listed in Table 11 to 13 for spectrally-matched horizonal-component time-histories, however, tend to be skewed toward the 84^{th}-percentile values. This preponderance of above-median values may be because the target scenario has a lower magnitude than most of the records used.

5.0 SUMMARY

Thirty-five sets of acceleration time-histories were developed for the design and analysis of the soil-structure systems proposed for the BSP site (i.e., 10 sets for 100-year, 10 sets for 475-year, 15 sets for 2,475-year). Each set has three components of earthquake ground motions: two horizontal and one vertical. Selected acceleration time-histories for each set were spectrally matched to the target horizontal and vertical scenario acceleration response spectra.

Scenario response spectra were developed as an alternative to using an envelope of ground motions from different earthquakes represented by the site UHRS. To cover the period range of interest from 0.01 to 10 seconds, two scenario acceleration response spectra were developed. One scenario captures the period range between the 0.01 and ~1 s of the UHRS. This scenario represents crustal and inslab subduction zone earthquakes occurring in the seismic sources labelled as “Vancouver Island Coast Mountains” and “Georgia Strait/Puget Sound”, respectively, in the 5th Generation Seismic Hazard Model developed by NRCan. The other scenario spectrum captures the spectral ordinates of the UHRS for periods greater than ~1 s and represents earthquakes of **M**8.5+ occurring in the Cascadia subduction interface seismic source. For the vertical component of ground motions, three scenario response spectra have been developed using the V/H ratios calculated in the GMTR project.

Spectral-matching results indicate that the response spectra of the 35 sets of acceleration time-histories generally coincide with the target horizontal and vertical scenario spectra and the spectral matching results meet the criteria specified in CSA S6-14 Section 4.4.3.6.

Golder notes, however, that the envelop response spectrum falls below the UHRS from 2015 NBCC at periods from about 1 to 2 seconds. If the fundamental period of the structure of interest ranges from about 1 to 2 seconds, then the scenario response spectra and associated earthquake acceleration time-histories for crustal/inslab or interface earthquake scenario should be scaled up by about 10% to 30% to equal the 2015 NBCC UHRS at the fundamental period of interest.

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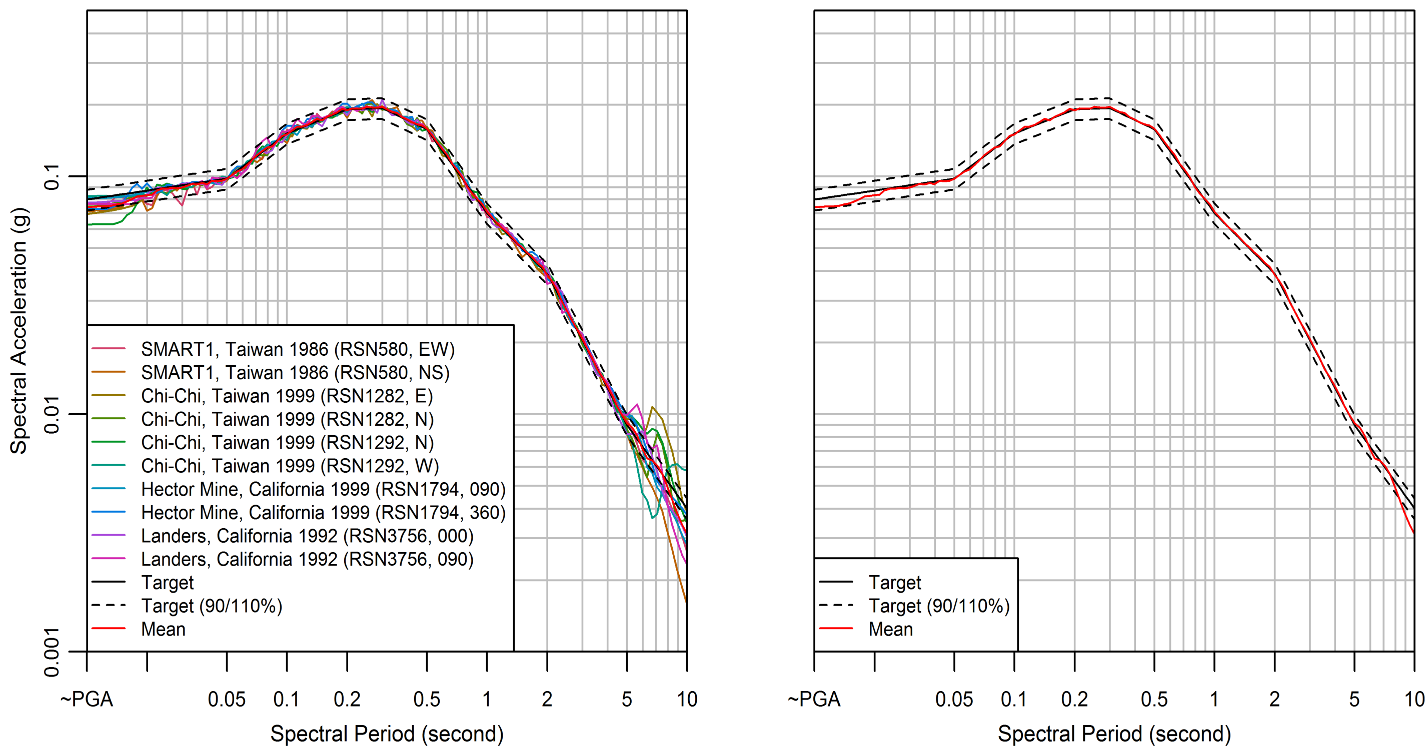
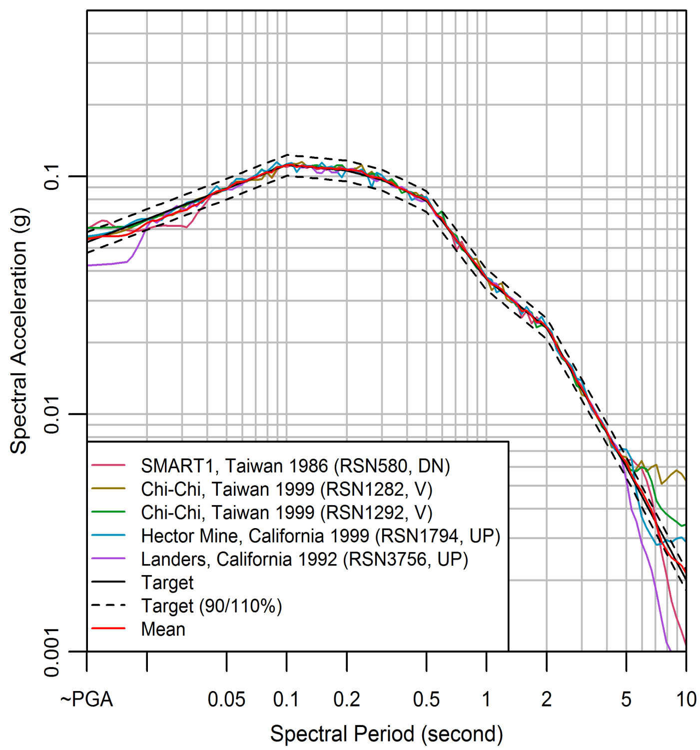
APPENDIX A

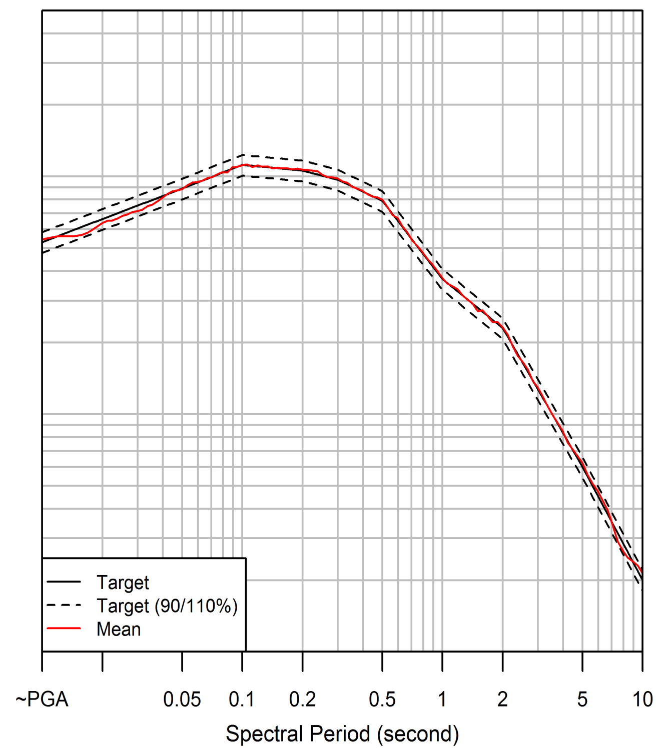
Spectrally-Matched Acceleration Time-Histories



CLIENT		PROJECT			
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**			
CONSULTANT	DD/MM/YYYY 11/27/2018	TITLE			
GOLDER	PREPARED AR	**COMPARISON OF HORIZONTAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 100−YEAR RETURN PERIOD**			
	DESIGN AR				
	REVIEW FL	PROJECT No.	PHASE	REV.	FIGURE
	APPROVED AH	1419105	7100	DRAFT	A1

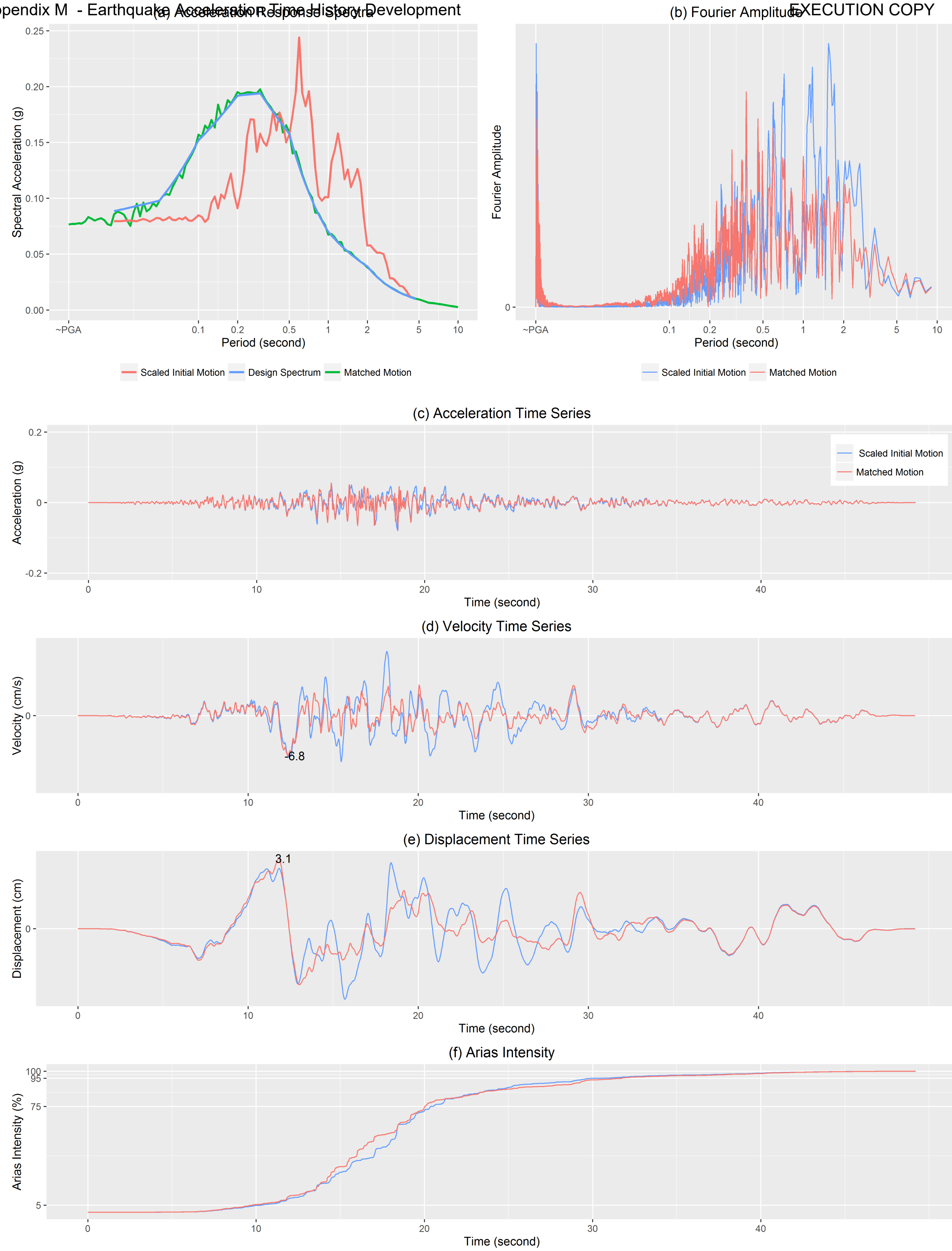
2018−11−27 16:37:00 FLI





CLIENT **STANTEC CONSULTANTS INC.**		PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**	
CONSULTANT GOLDER	DD/MM/YYYY: 11/27/2018 PREPARED: AR DESIGN: AR REVIEW: FL APPROVED: AH	TITLE **COMPARISON OF VERTICAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 100−YEAR RETURN PERIOD**	
		PROJECT No. 1419105	PHASE 7100
		REV. DRAFT	FIGURE A2

2018-11-27 16:37:03 FLi



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

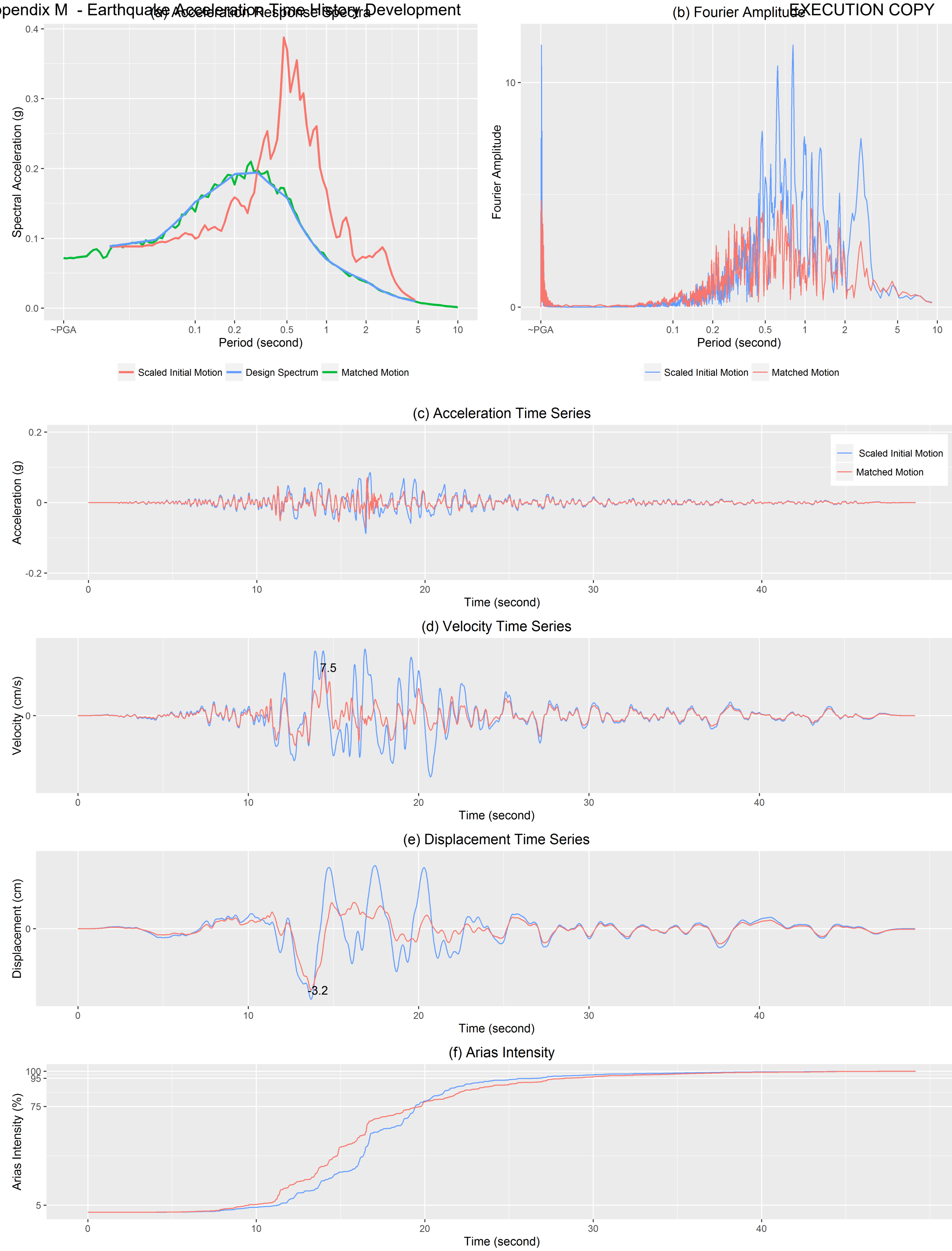
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A3

2018-11-27 16:37:05 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

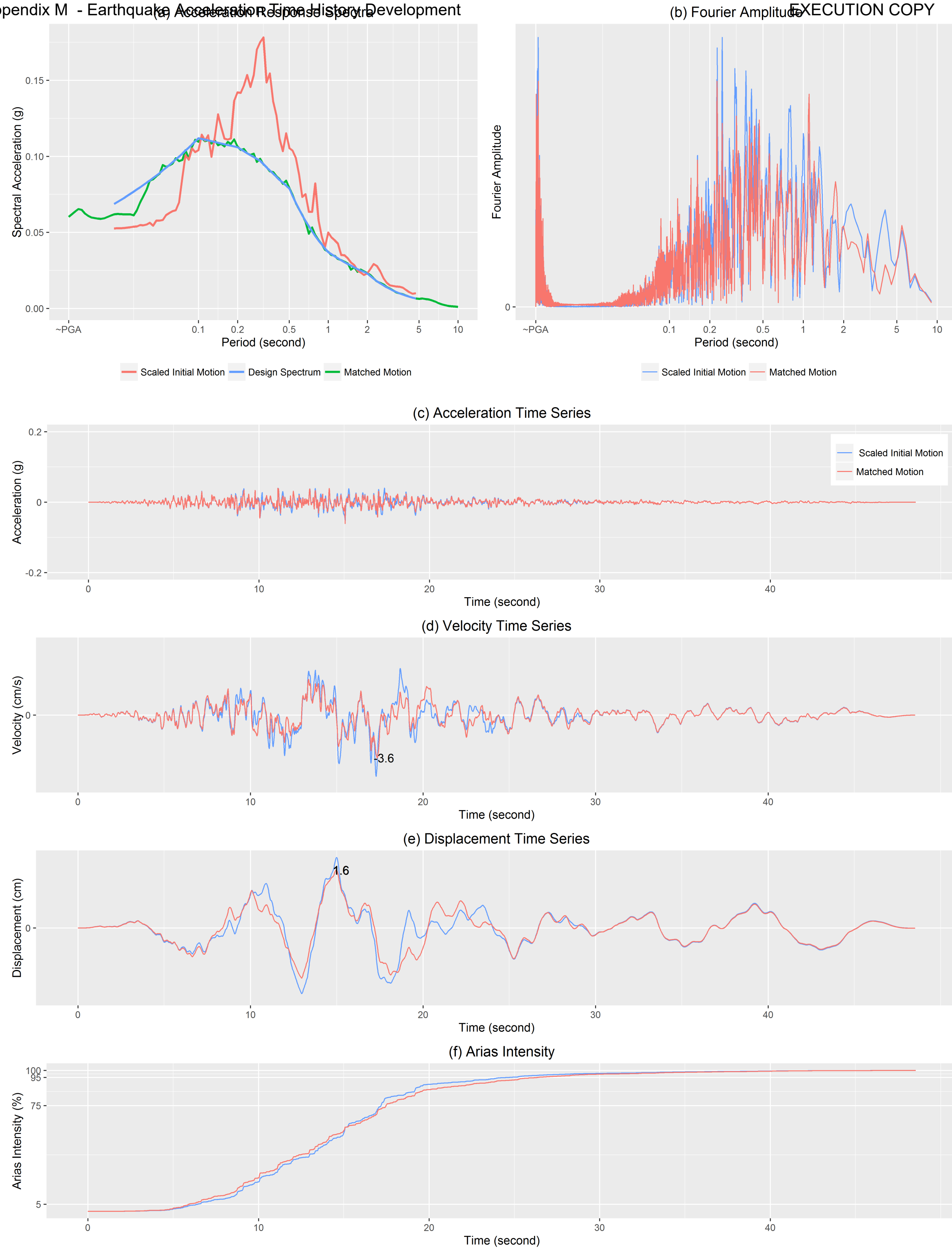
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A4

2018-11-27 16:37:14 FLi

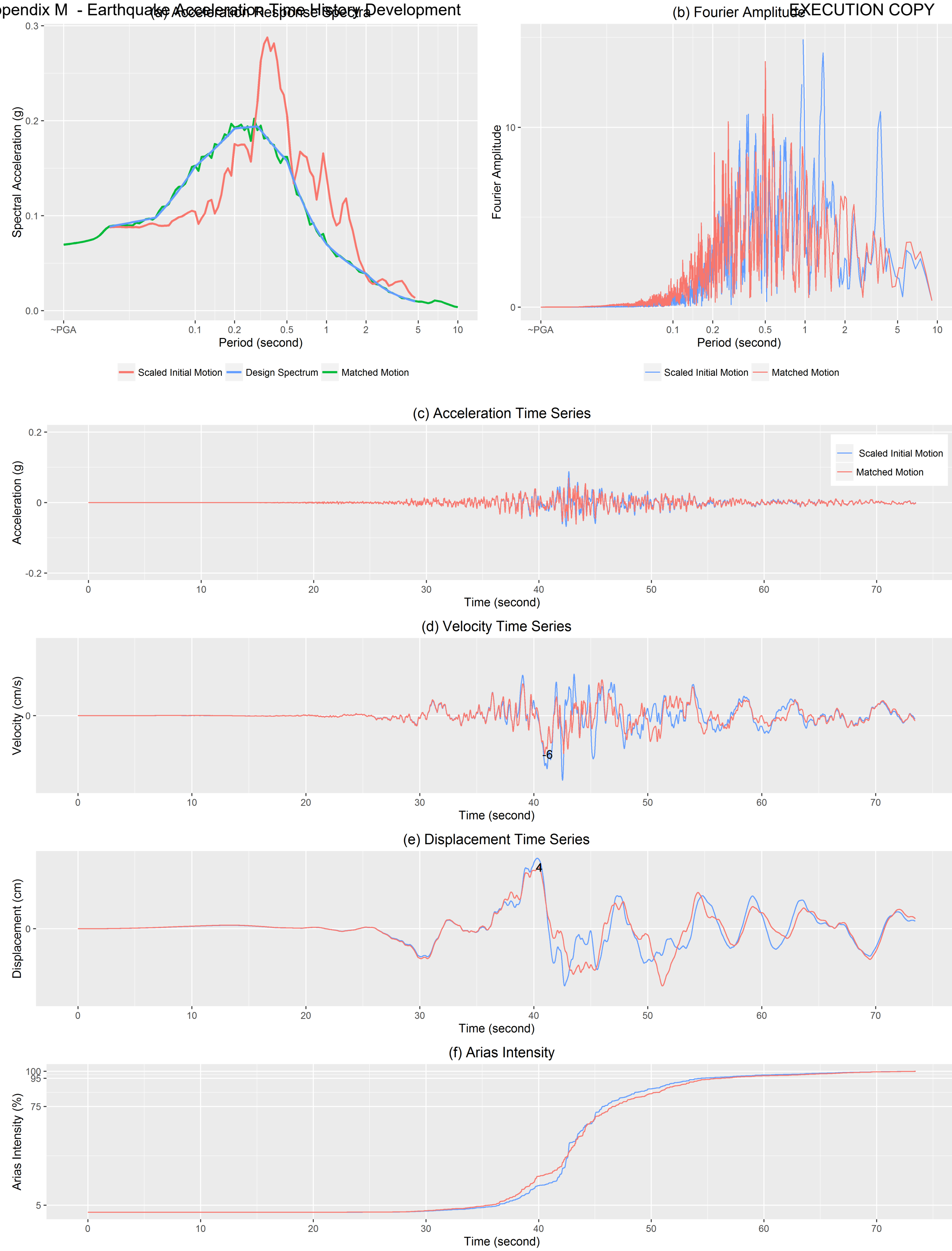


CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT			TITLE
GOLDER	DD/MM/YYYY	11/27/2018	**SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, DN)**
	PREPARED	AR	
	DESIGN	AR	
	REVIEW	FL	
	APPROVED	AH	

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A5

2018-11-27 16:37:22 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

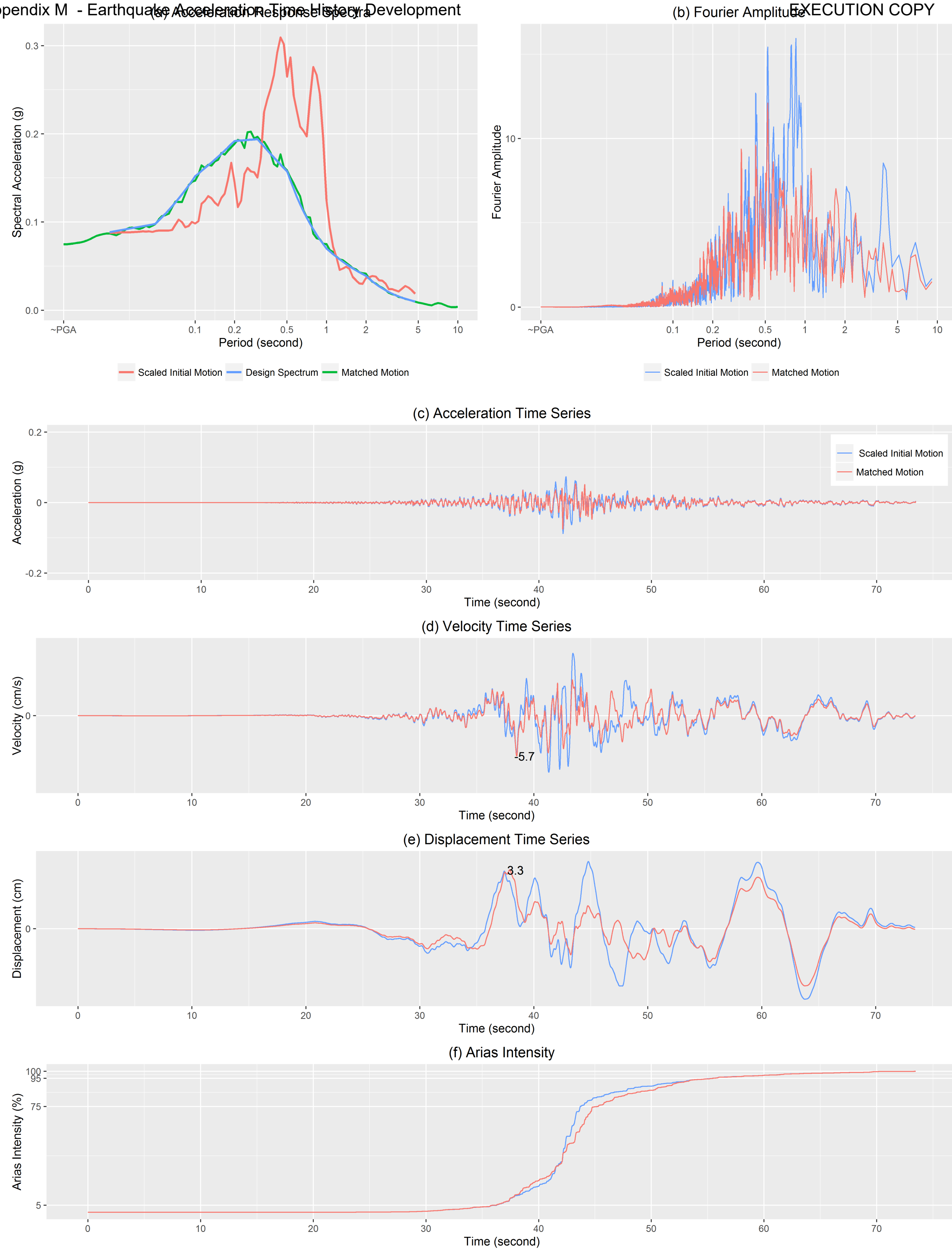
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A6

2018-11-27 16:37:30 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

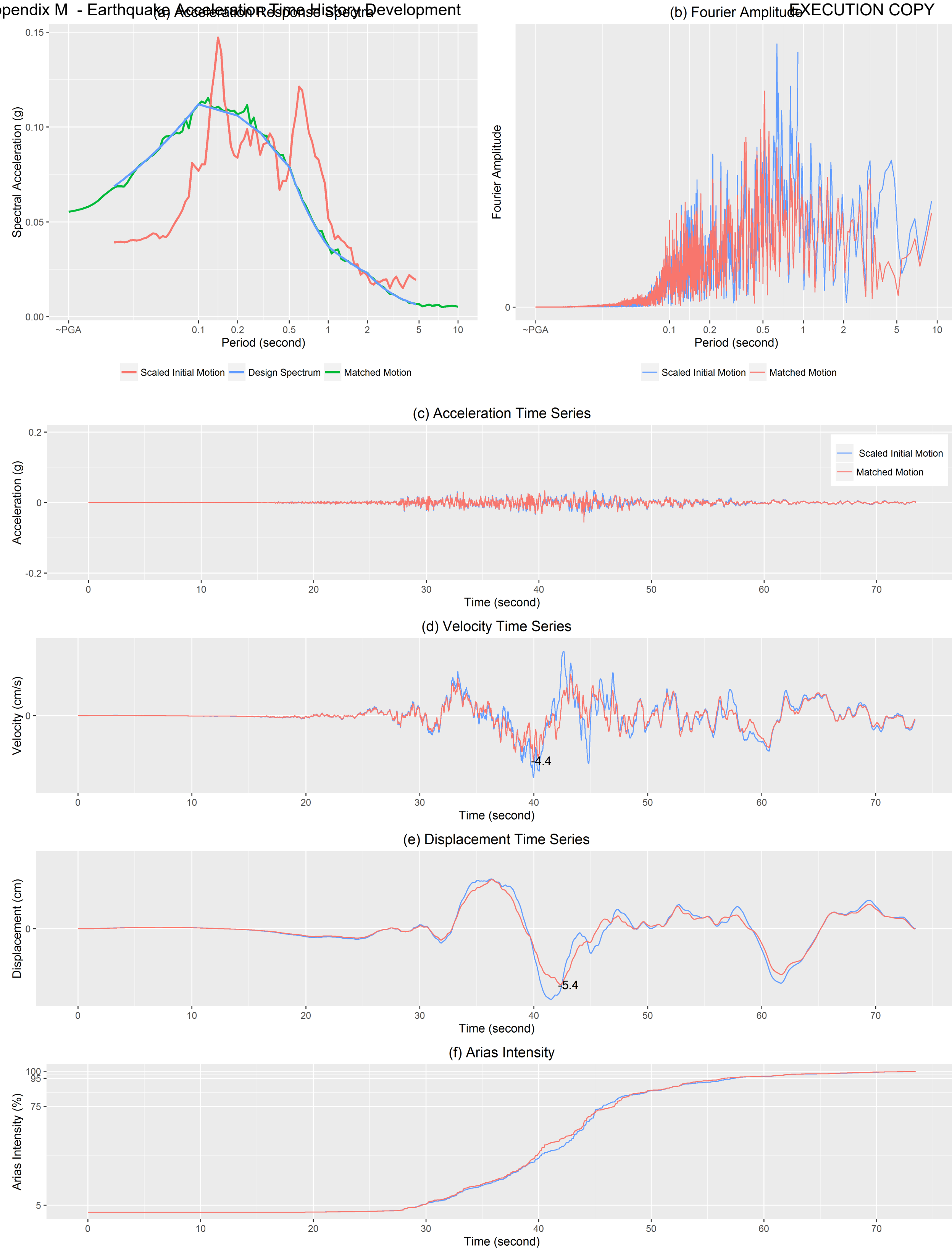
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A7

2018-11-27 16:37:38 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

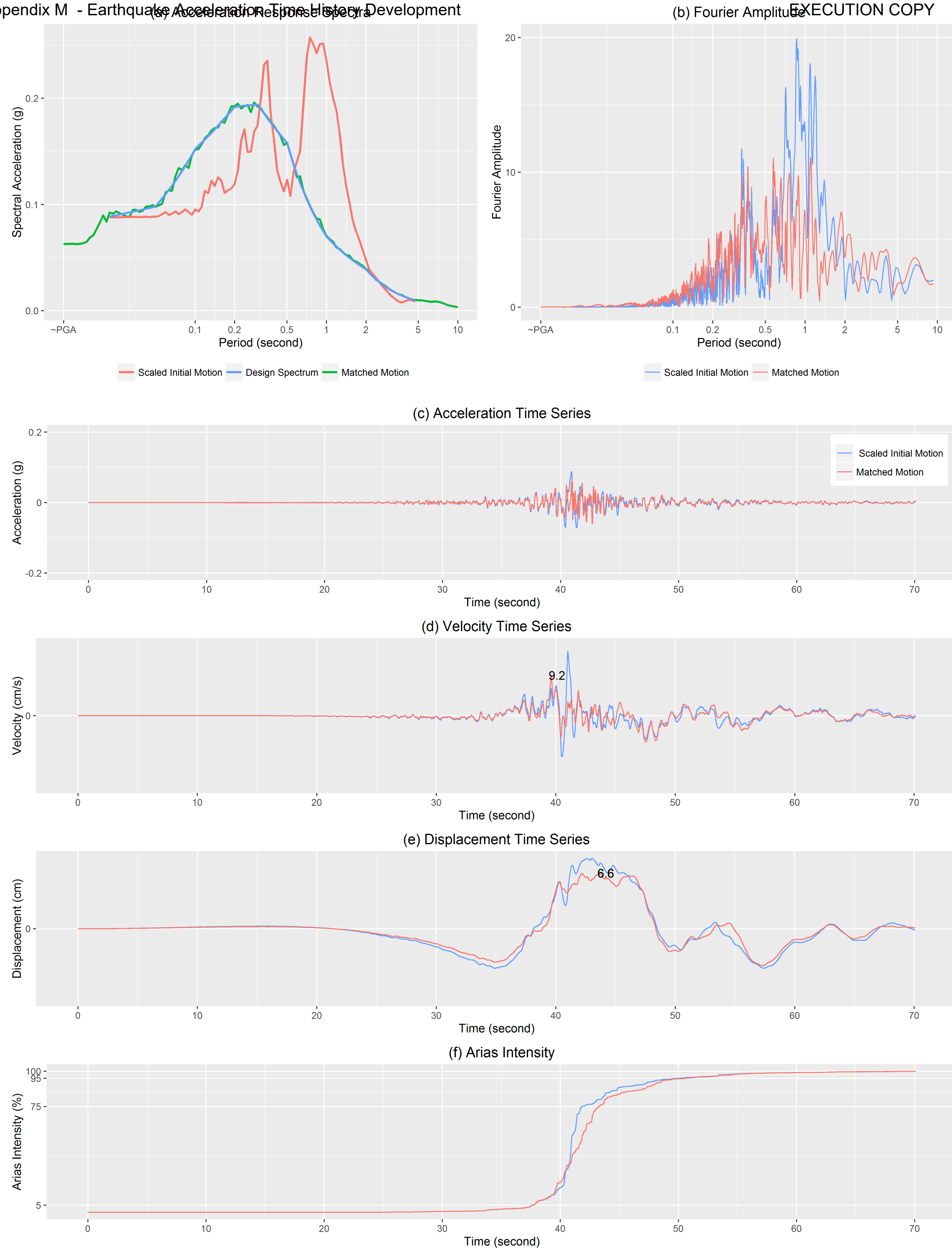
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A8

2018-11-27 16:37:46 FLI



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

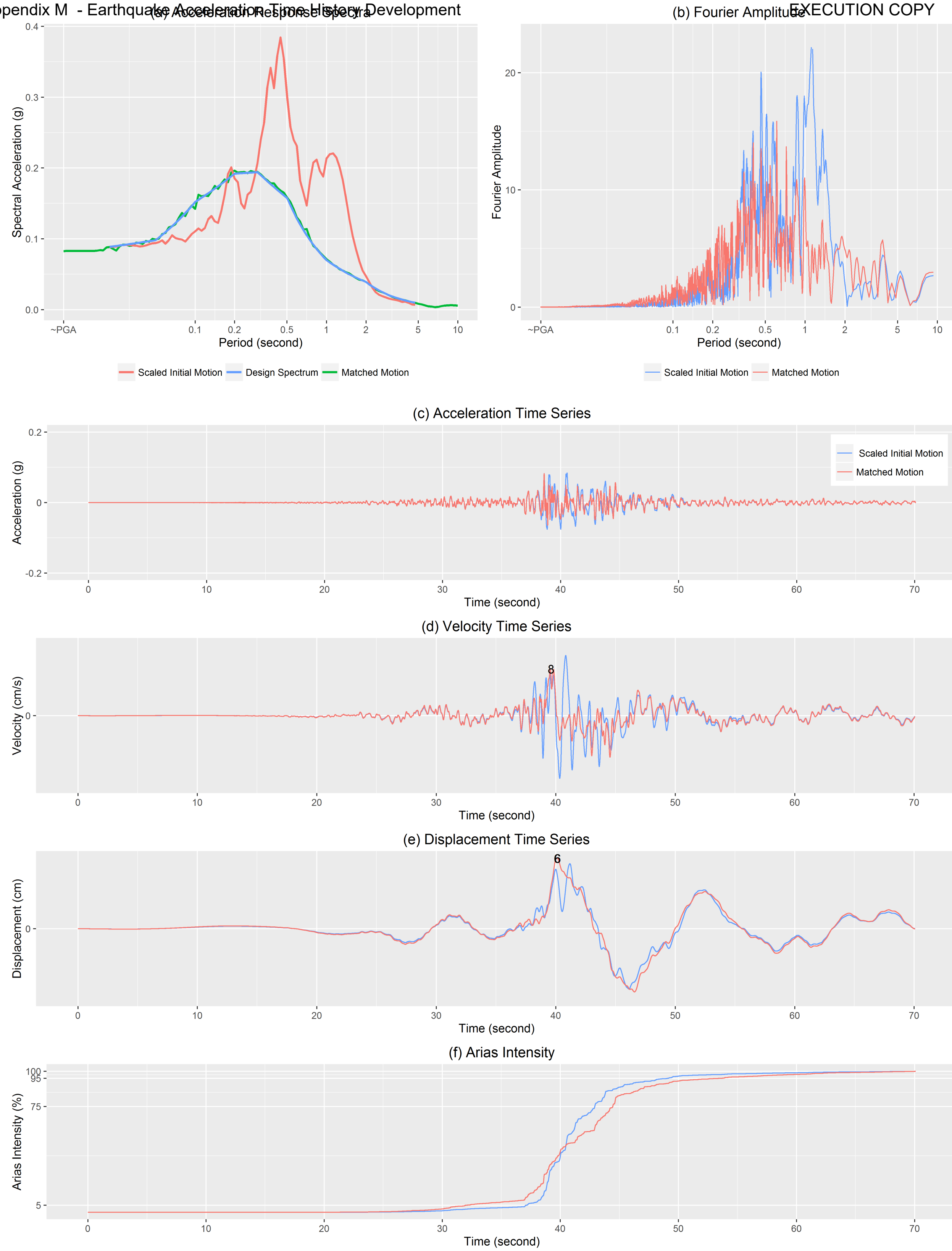
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A9

2018-11-27 16:37:54 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

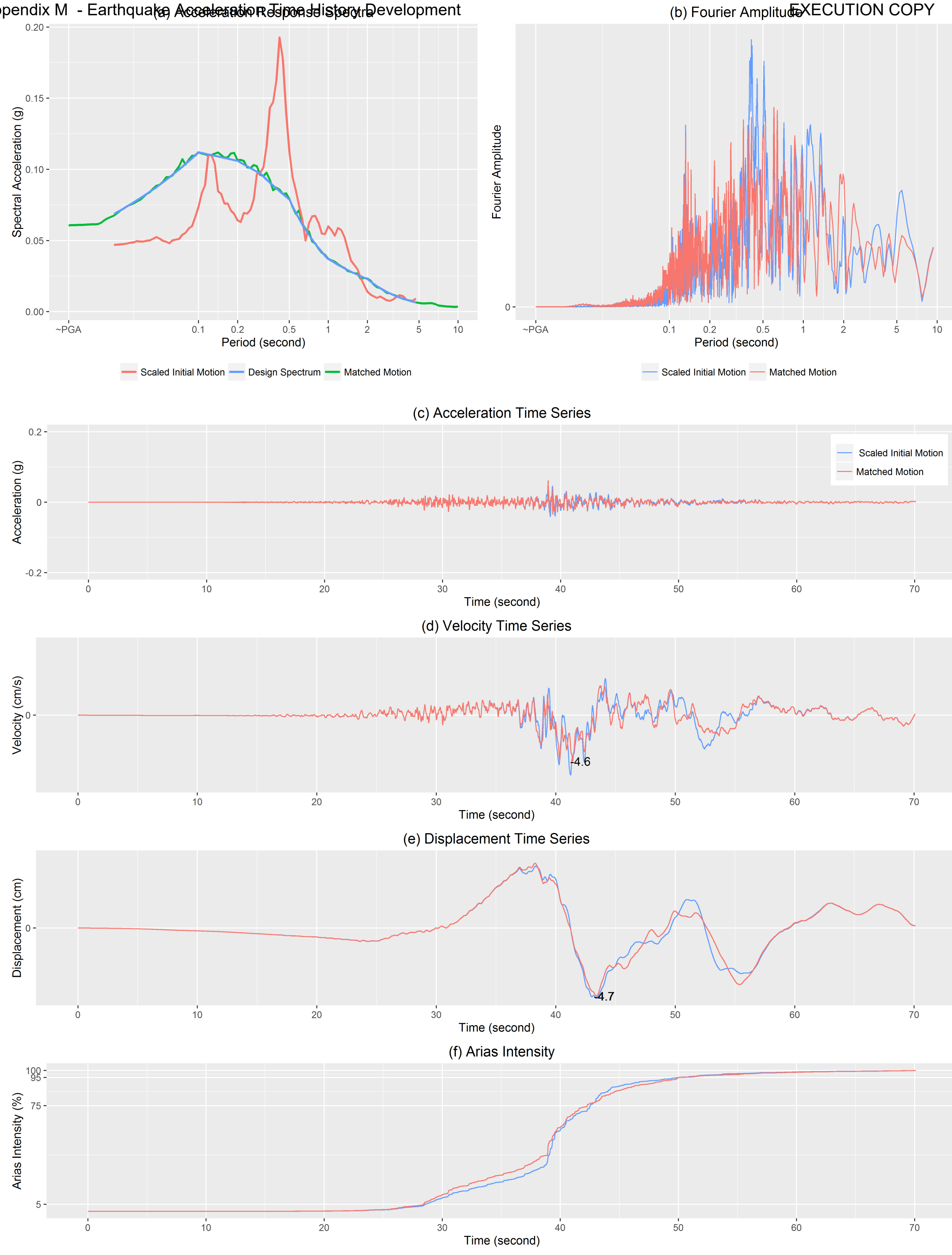
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, W)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A10

2018-11-27 16:38:02 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

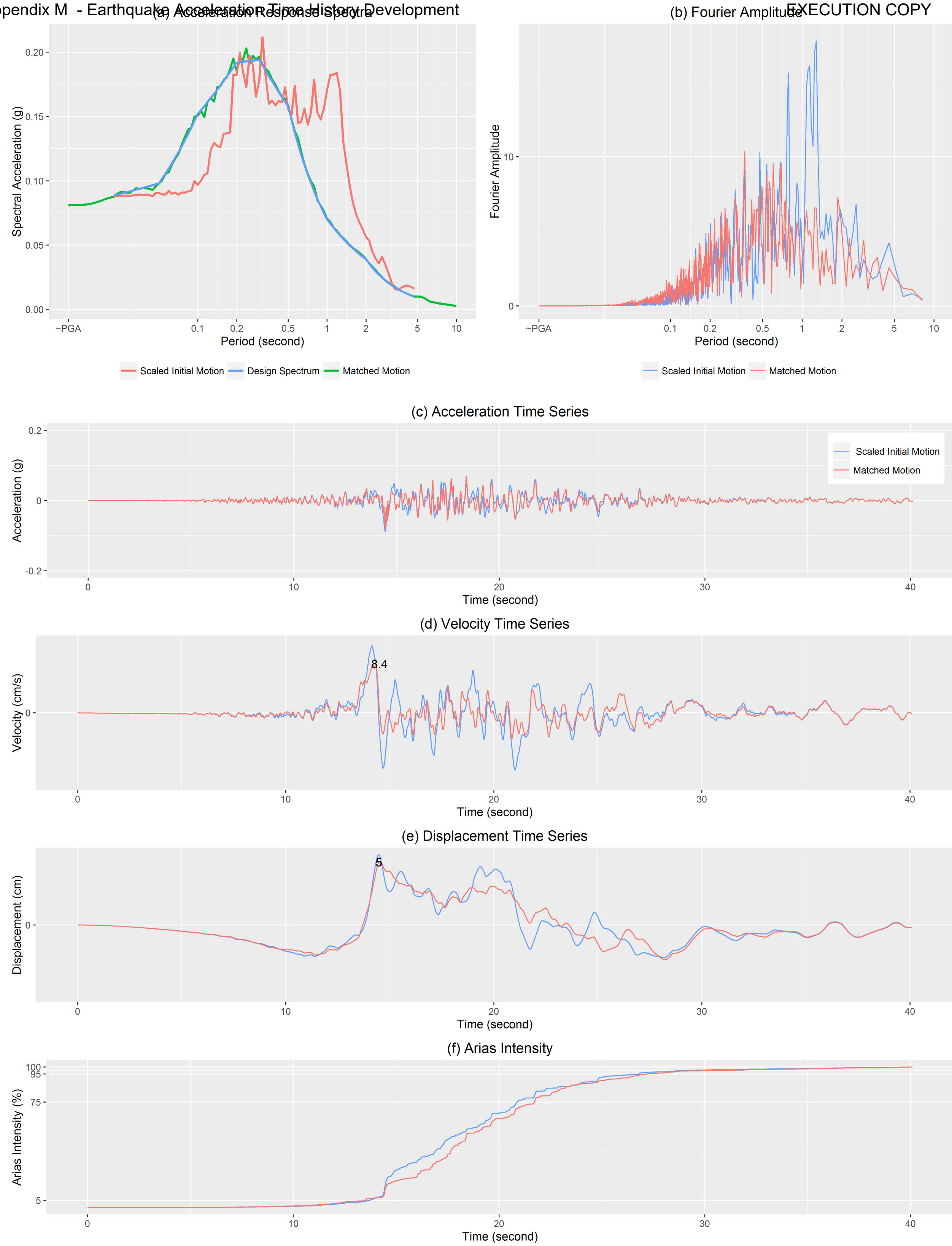
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A11

2018-11-27 16:38:09 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

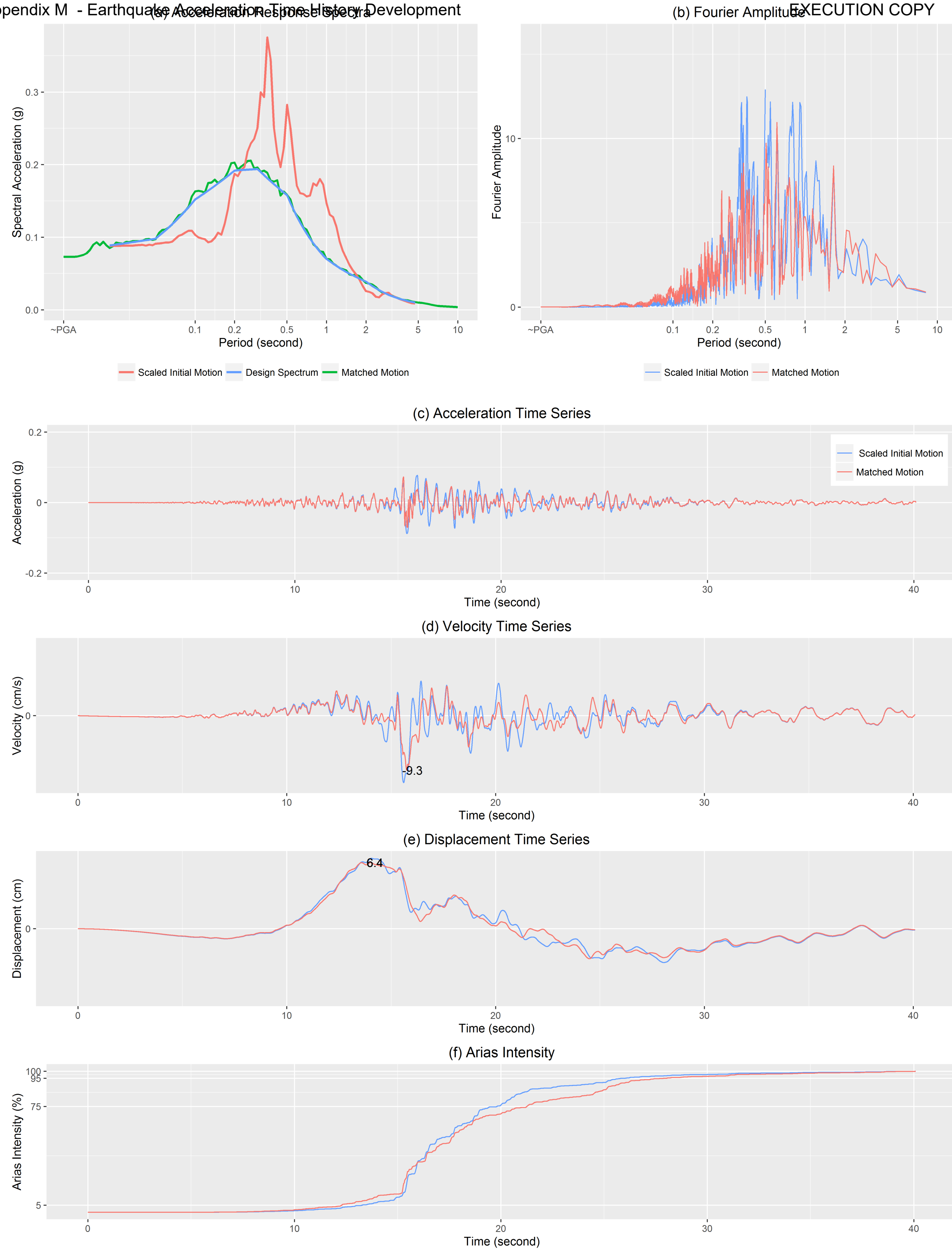
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A12

2018−11−27 16:38:17 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

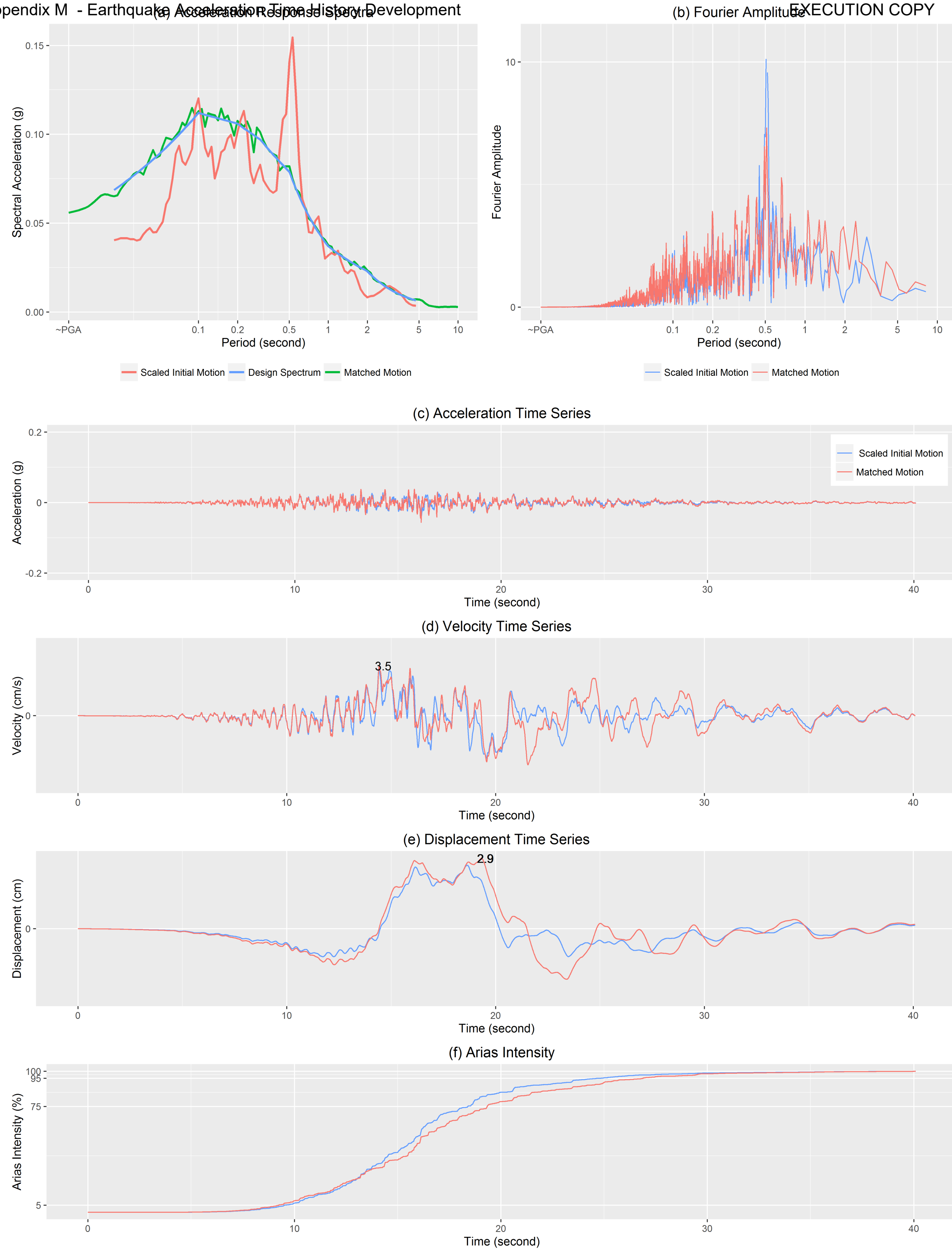
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 360)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A13

2018-11-27 16:38:25 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

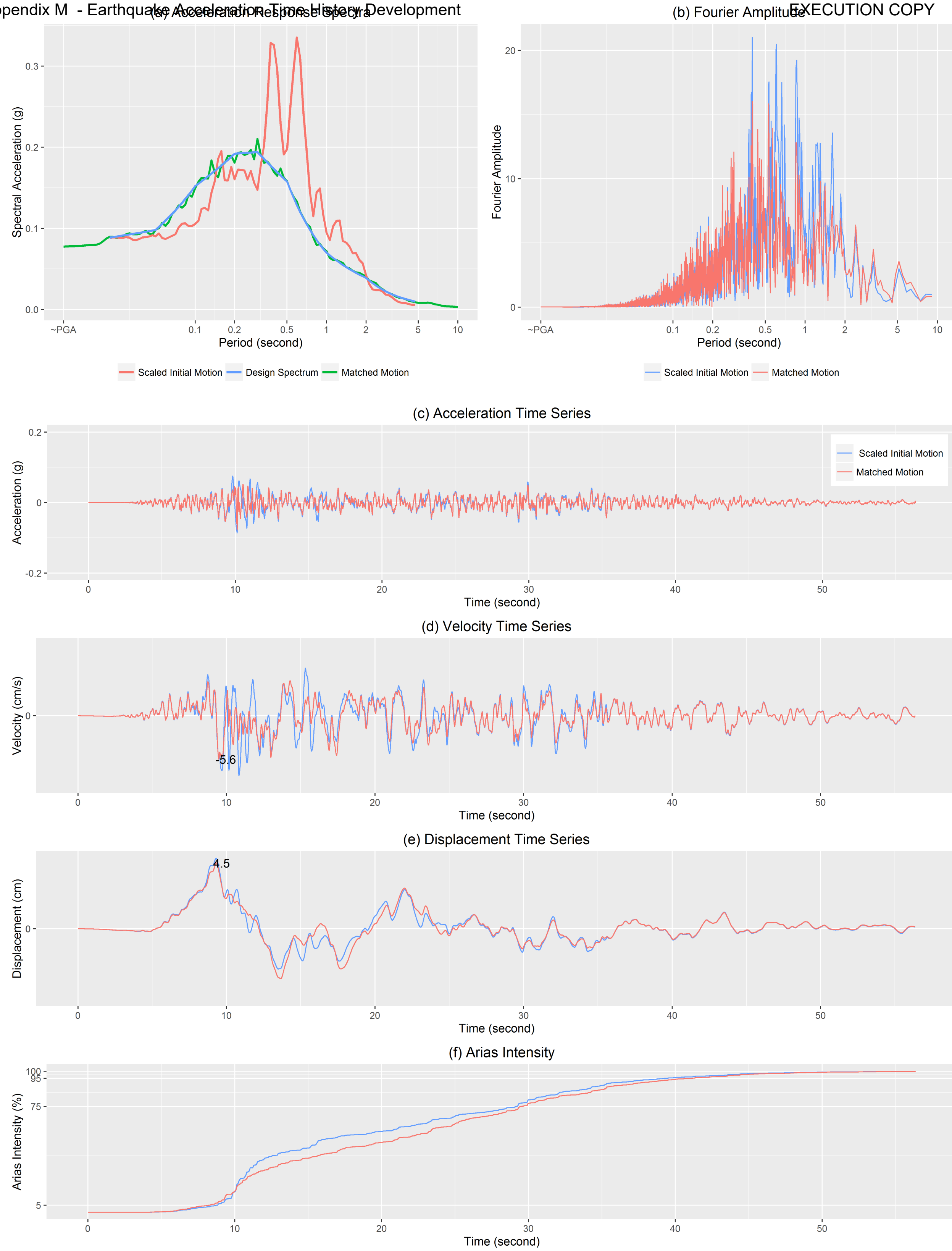
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A14

2018-11-27 16:38:33 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

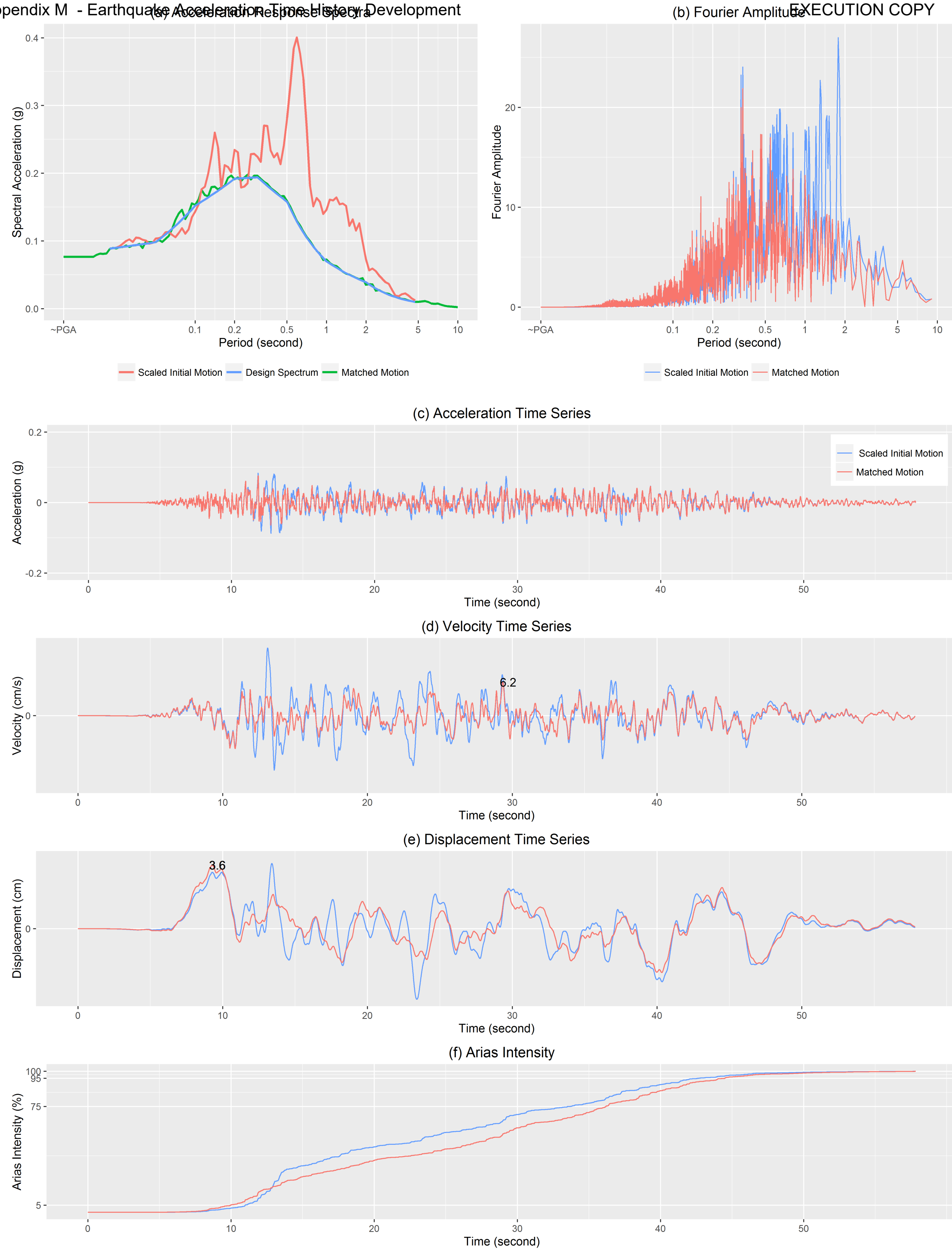
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 0)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A15

2018−11−27 16:38:41 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

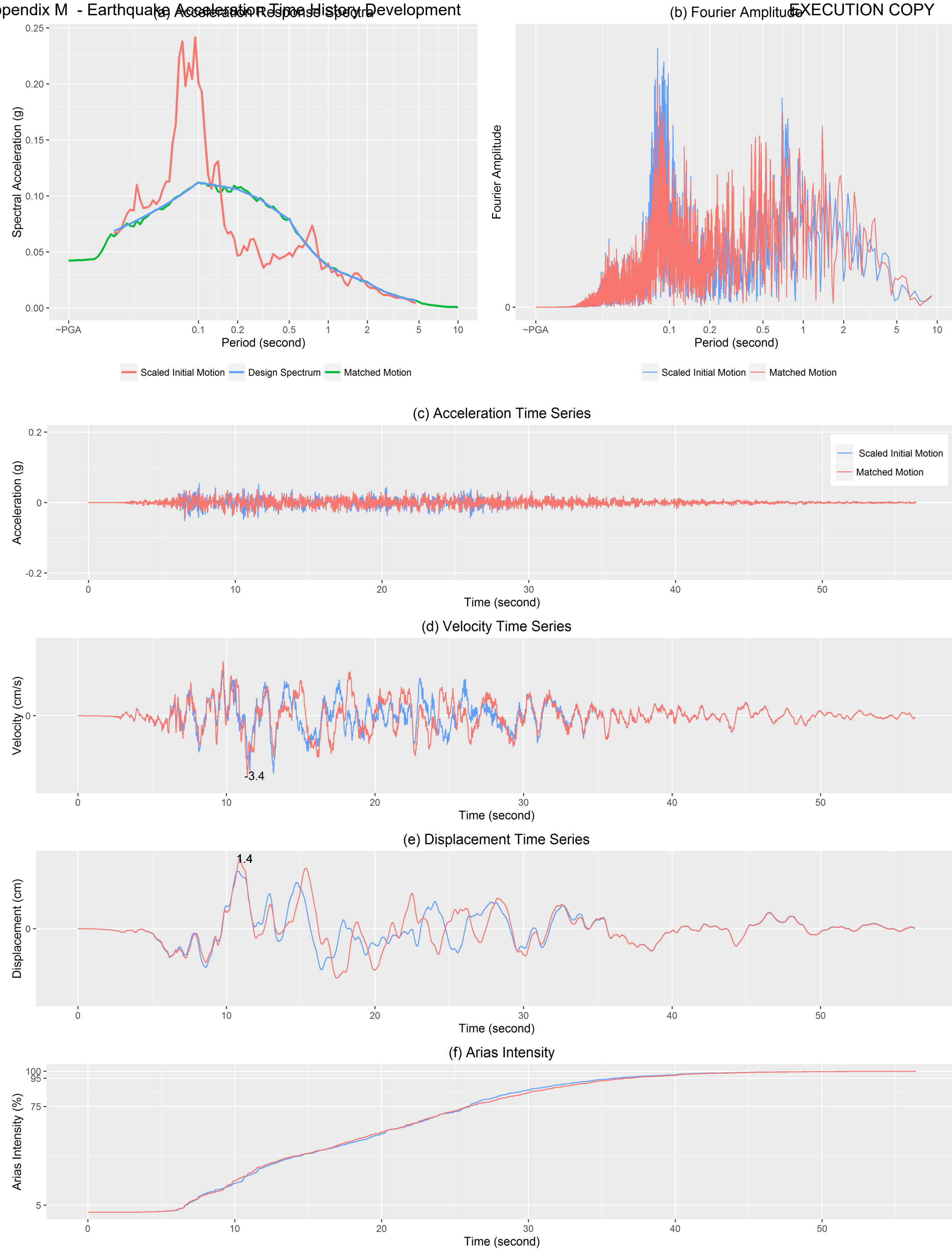
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 90)

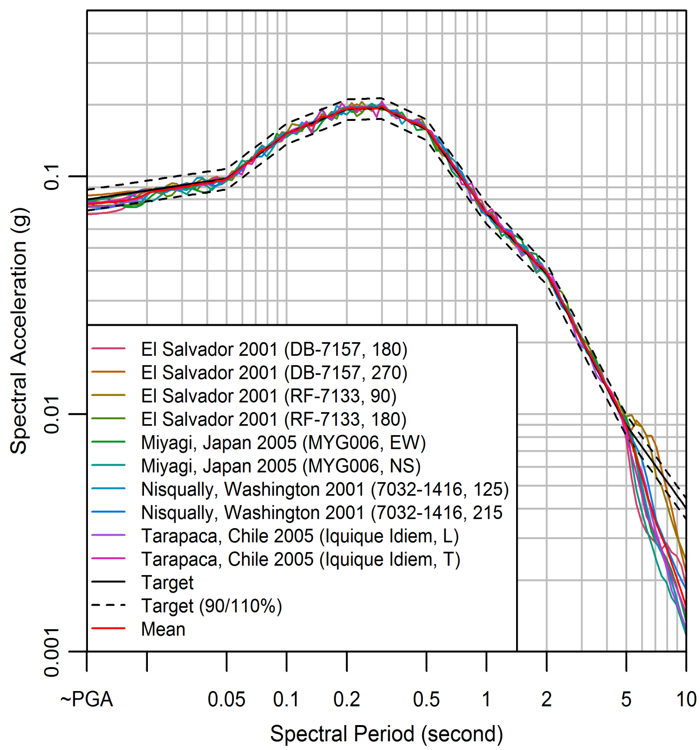
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A16

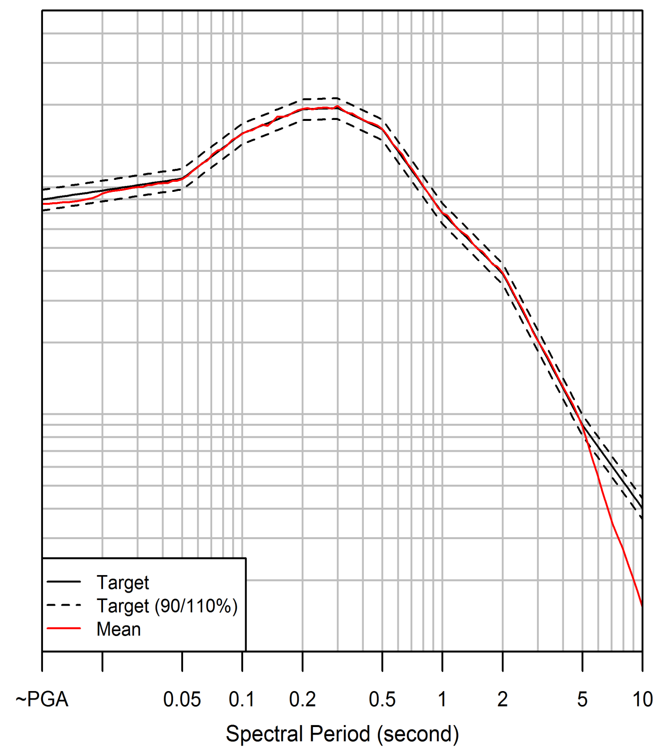
2018-11-27 16:38:48 FLi



CLIENT **STANTEC CONSULTANTS INC.**		PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**	
CONSULTANT GOLDER	DD/MM/YYYY 11/27/2018 PREPARED AR DESIGN AR REVIEW FL APPROVED AH	TITLE **SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), UP)**	
		PROJECT No. 1419105	PHASE 7100
		REV. DRAFT	FIGURE A17

2018-11-27 16:38:56 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

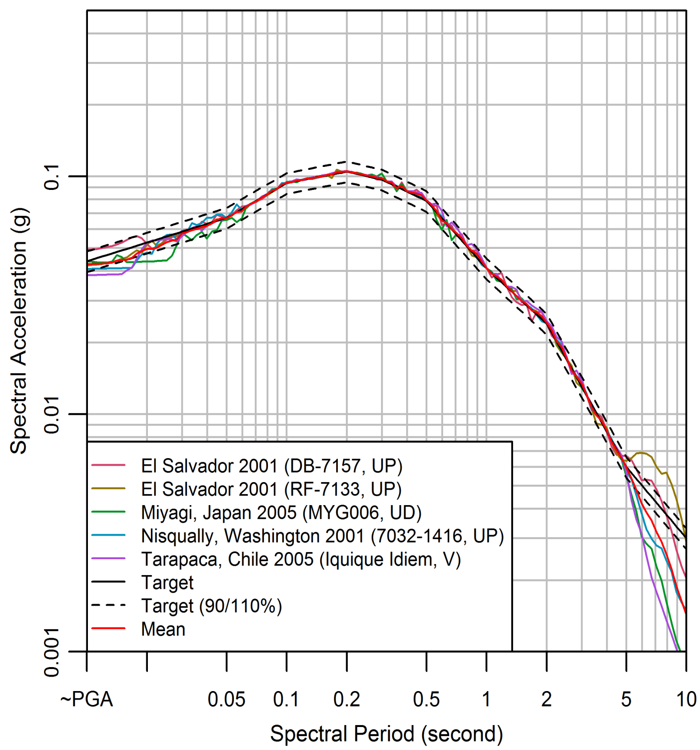
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

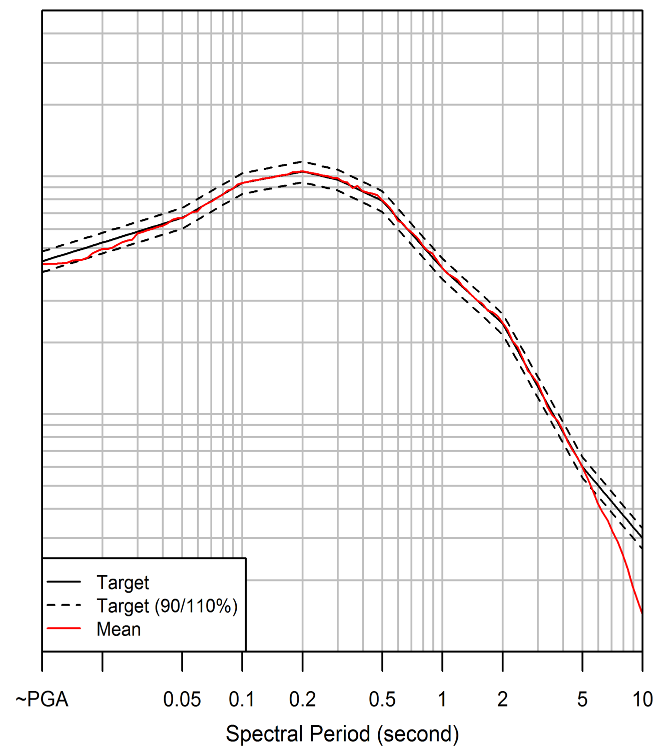
TITLE

COMPARISON OF HORIZONTAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 100−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A18

2018−11−27 16:39:04 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

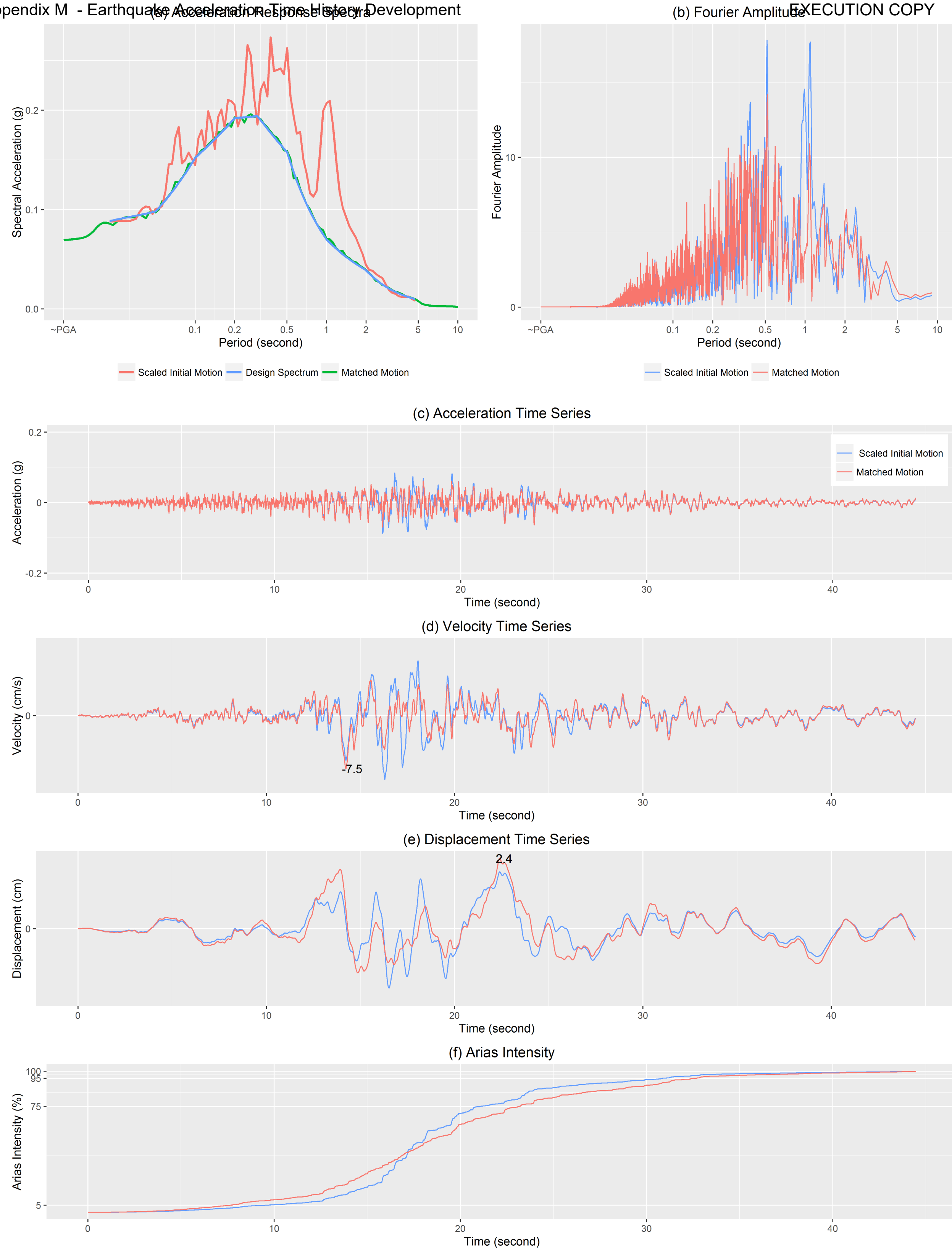
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF VERTICAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 100−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A19

2018−11−27 16:39:07 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

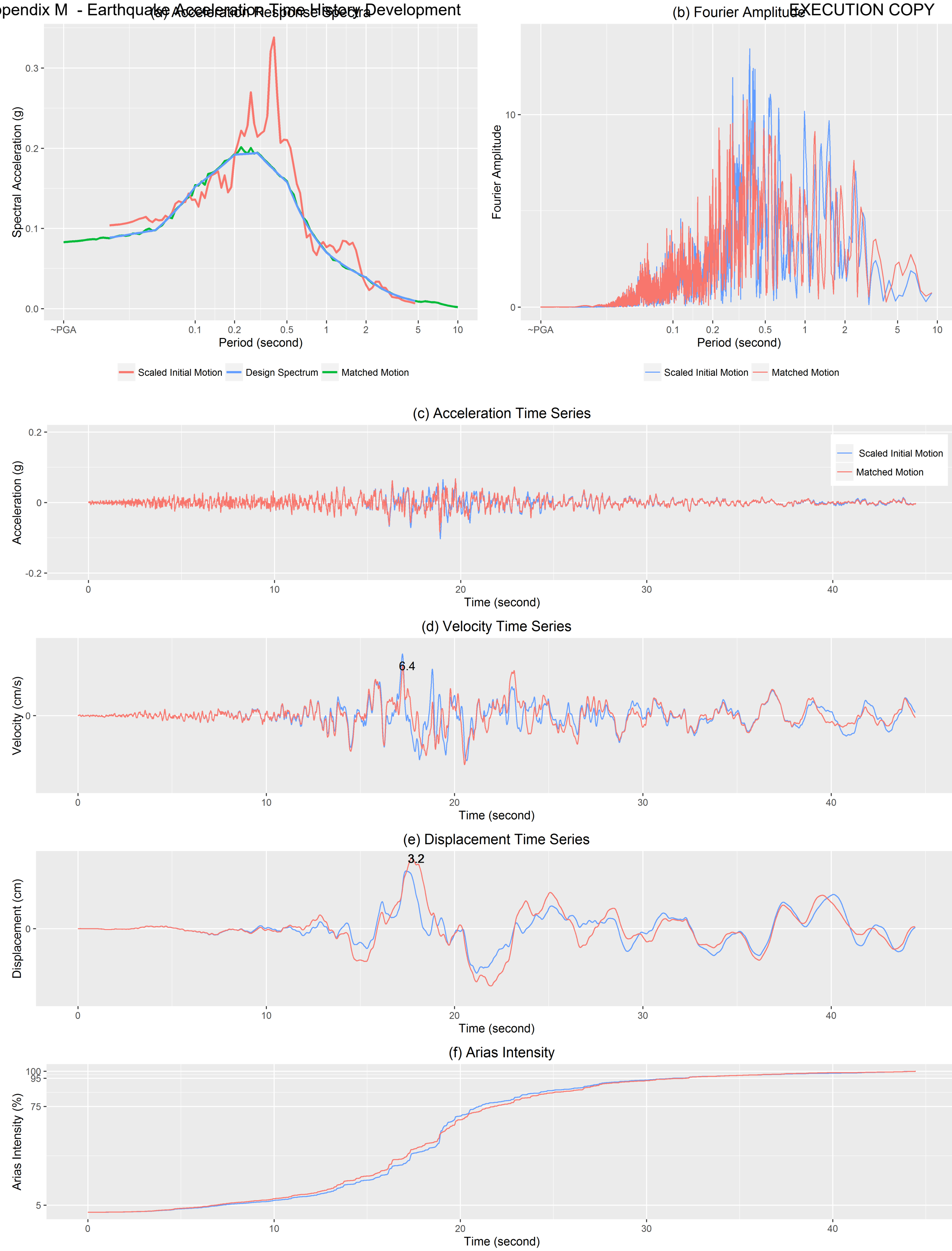
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 180)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A20

2018-11-27 16:39:09 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

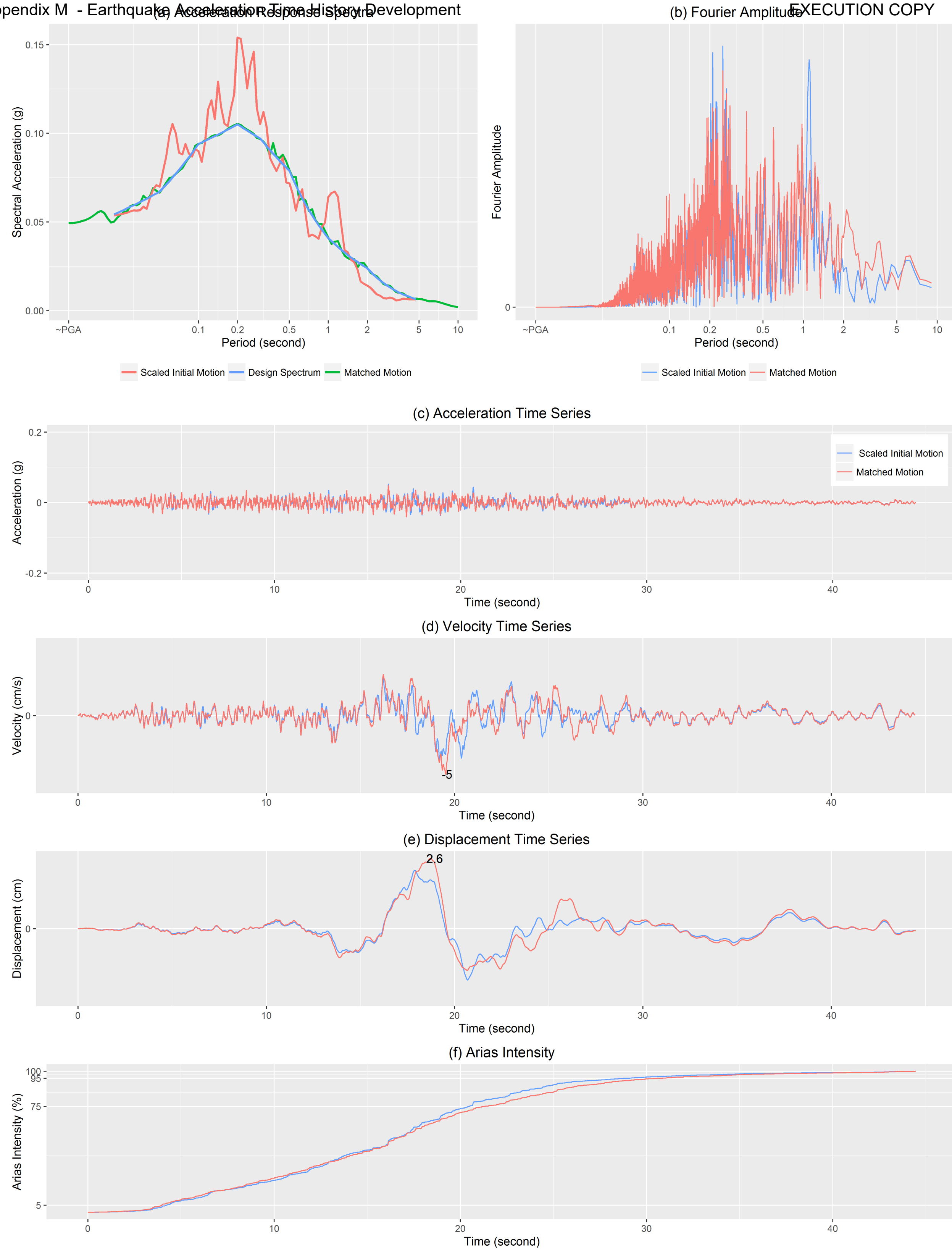
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 270)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A21

2018-11-27 16:39:17 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

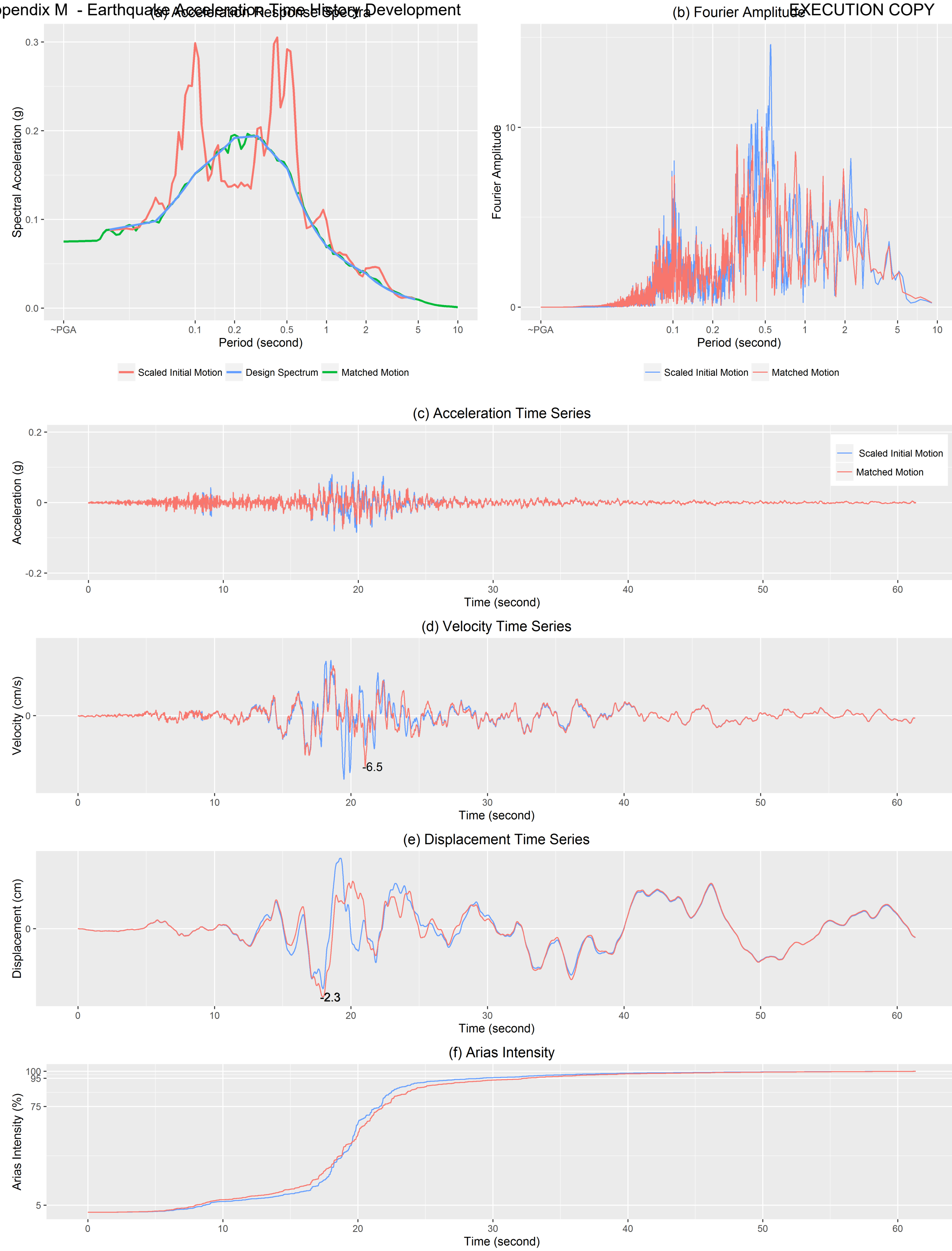
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, DB, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A22

2018-11-27 16:39:25 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

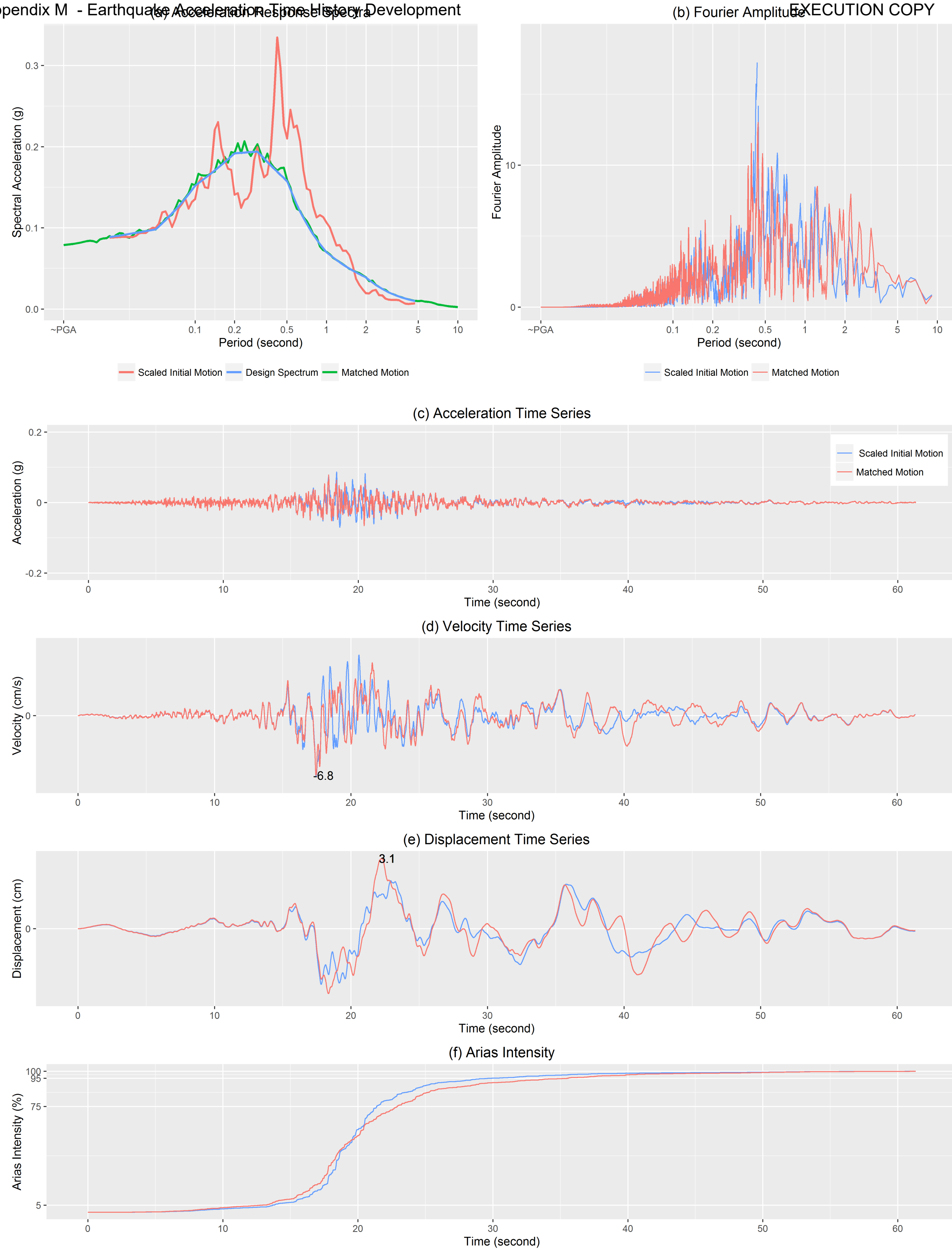
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 180)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A23

2018-11-27 16:39:33 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

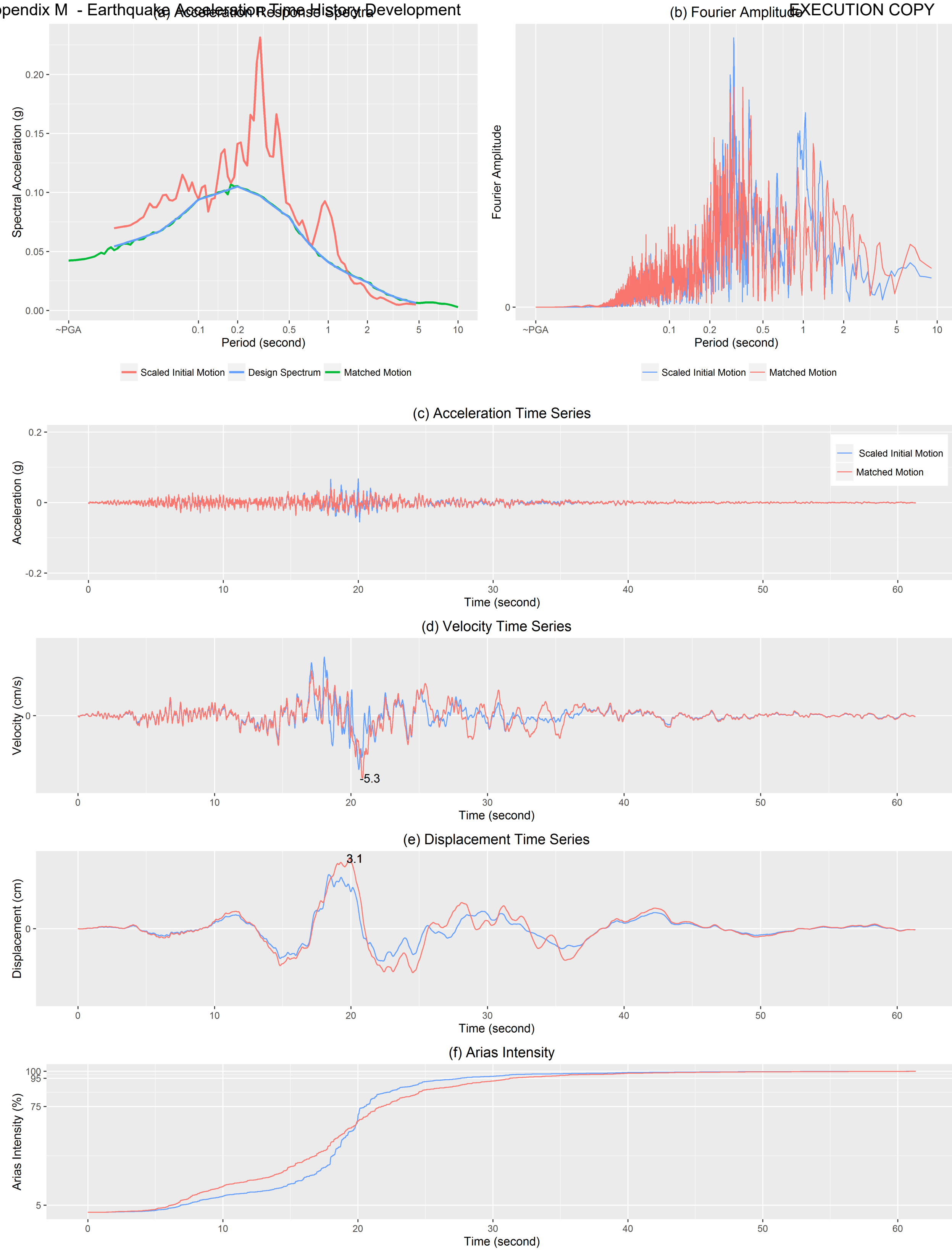
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A24

2018-11-27 16:39:40 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

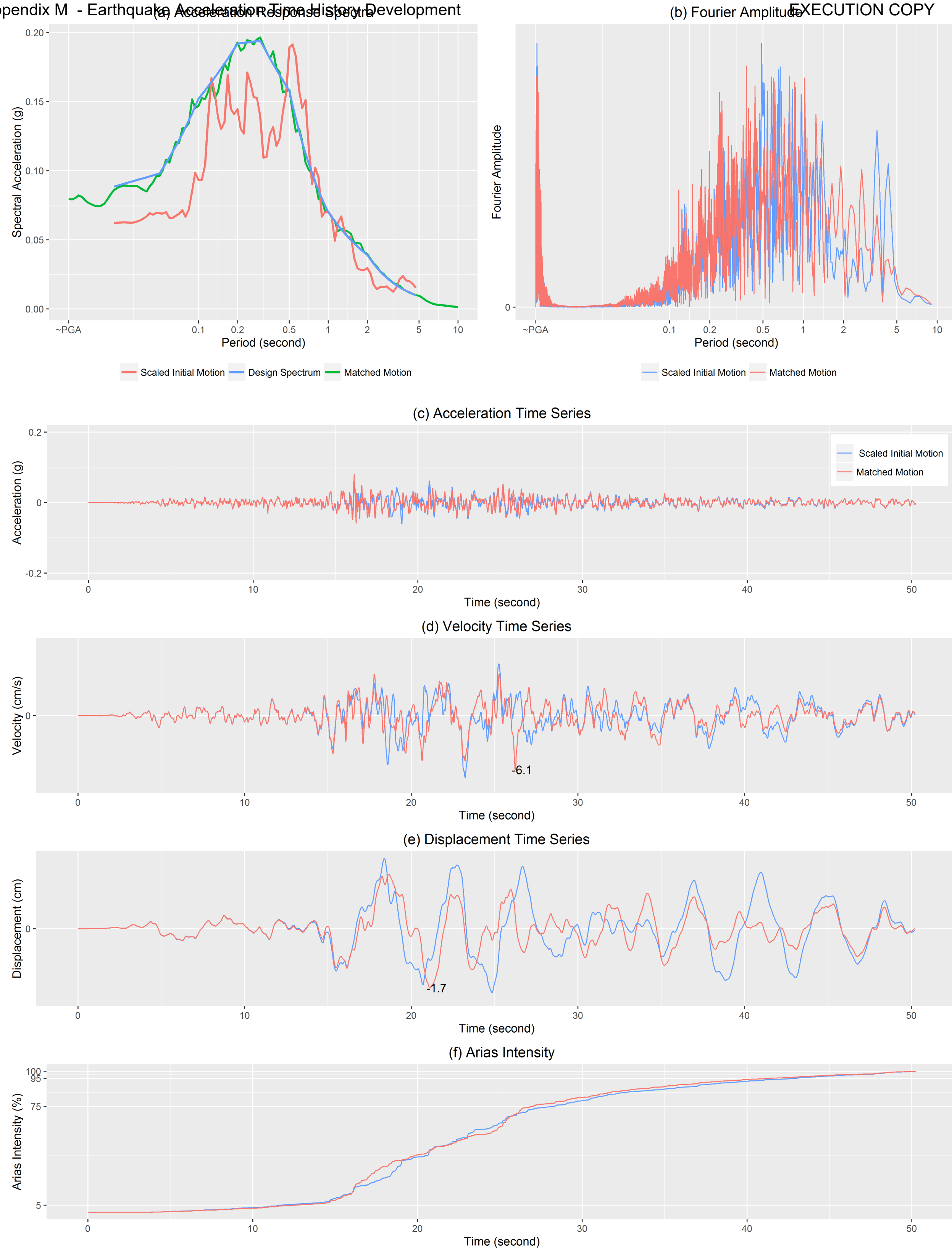
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD EL SALVADOR (2001, RF, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A25

2018-11-27 16:39:48 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

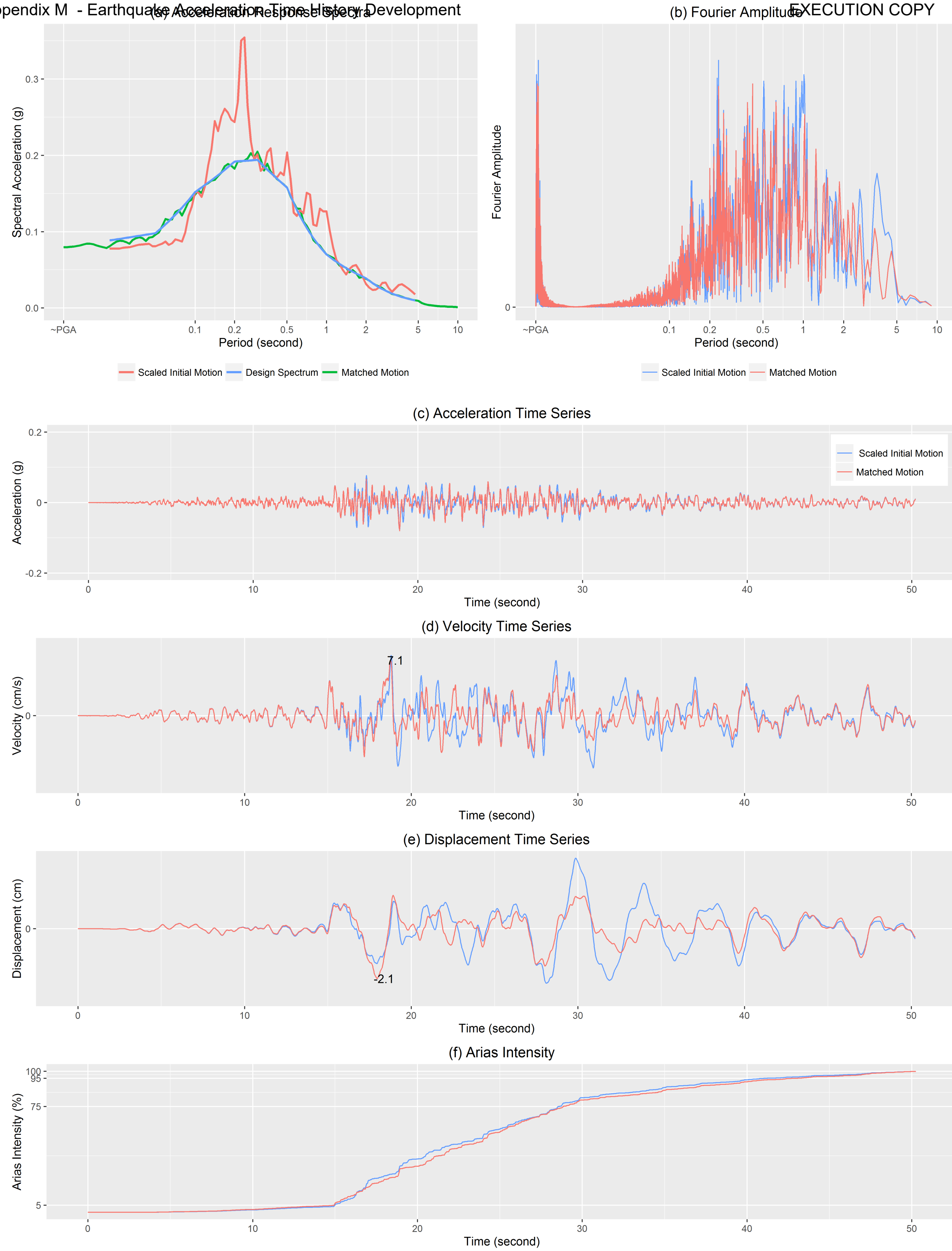
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD MIYAGI (2005, MYG006, EW)

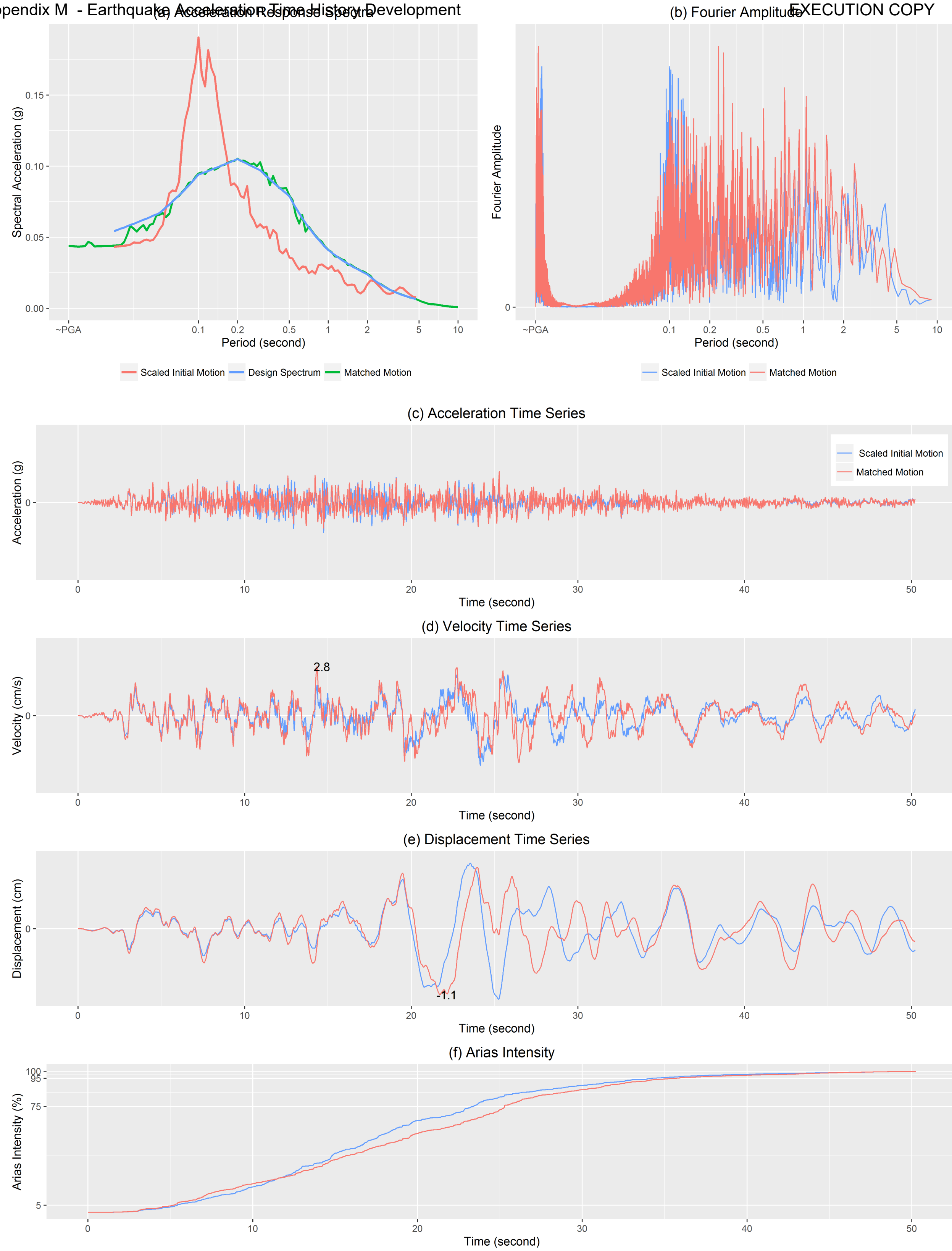
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A26

2018−11−27 16:39:56 FLi



CLIENT		PROJECT
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**
CONSULTANT	DD/MM/YYYY 11/27/2018	TITLE
GOLDER	PREPARED AR	**SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD MIYAGI (2005, MYG006, NS)**
	DESIGN AR	
	REVIEW FL	PROJECT No. 1419105 · PHASE 7100 · REV. DRAFT · FIGURE A27
	APPROVED AH	

2018-11-27 16:40:04 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

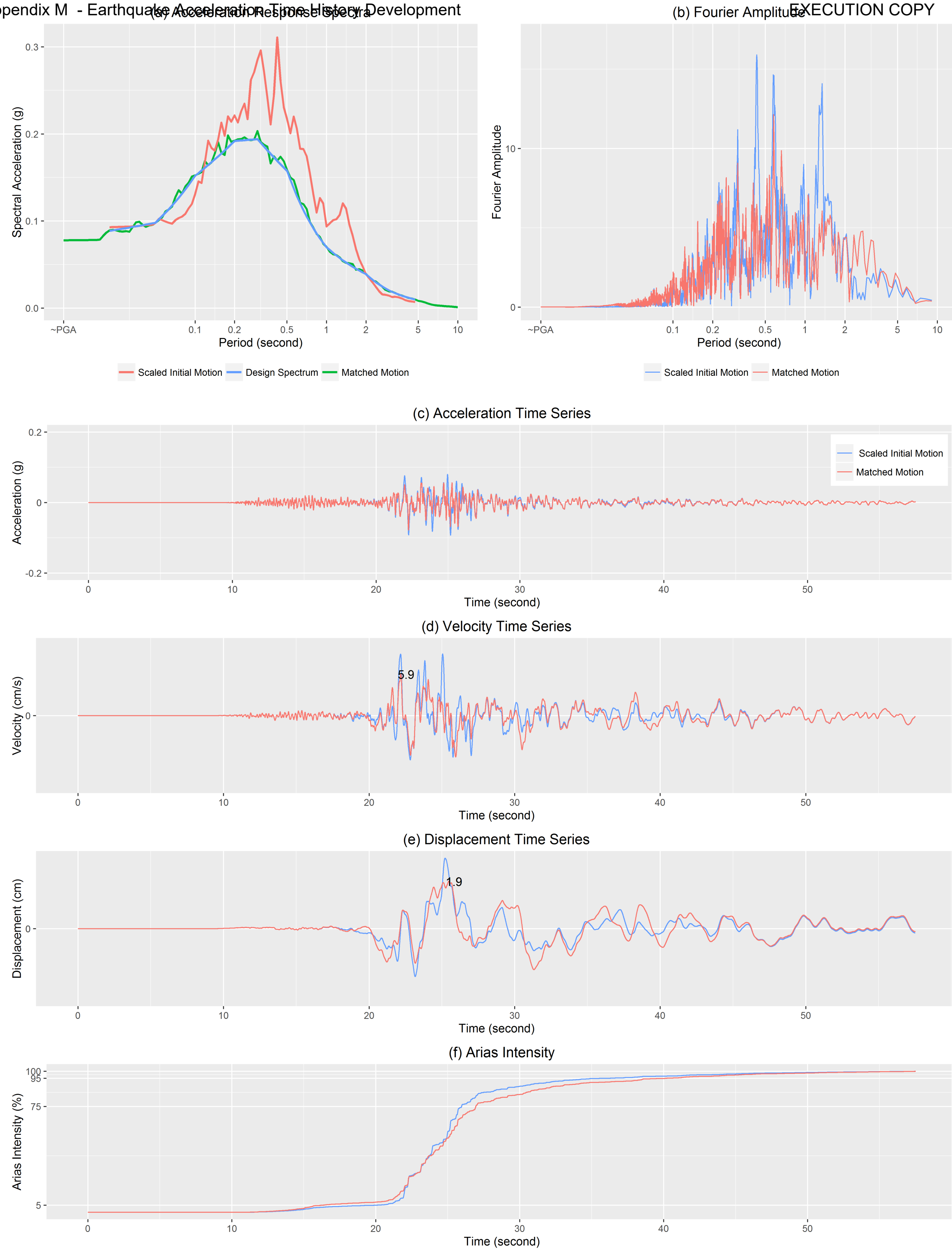
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD MIYAGI (2005, MYG006, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A28

2018−11−27 16:40:12 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

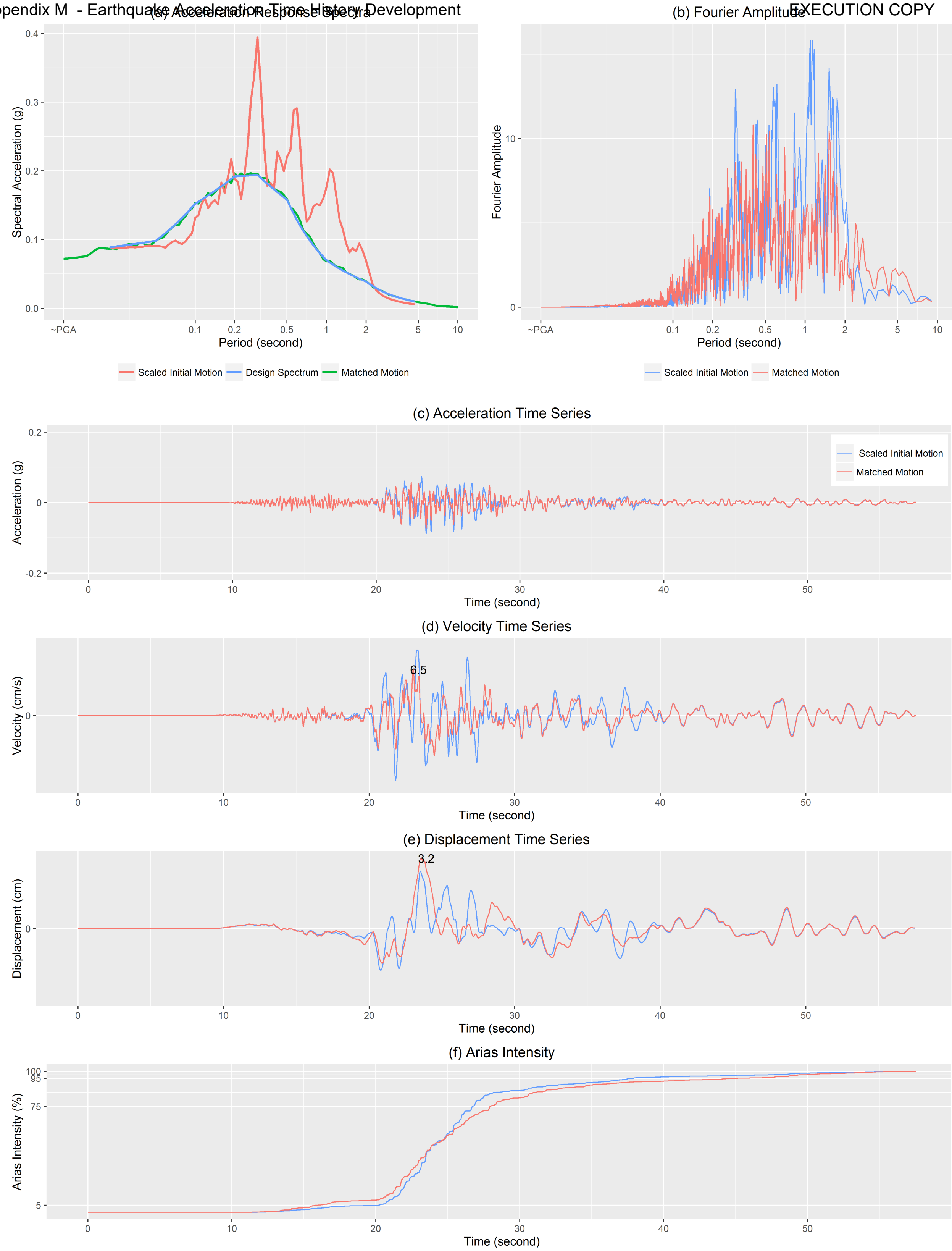
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 125)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A29



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

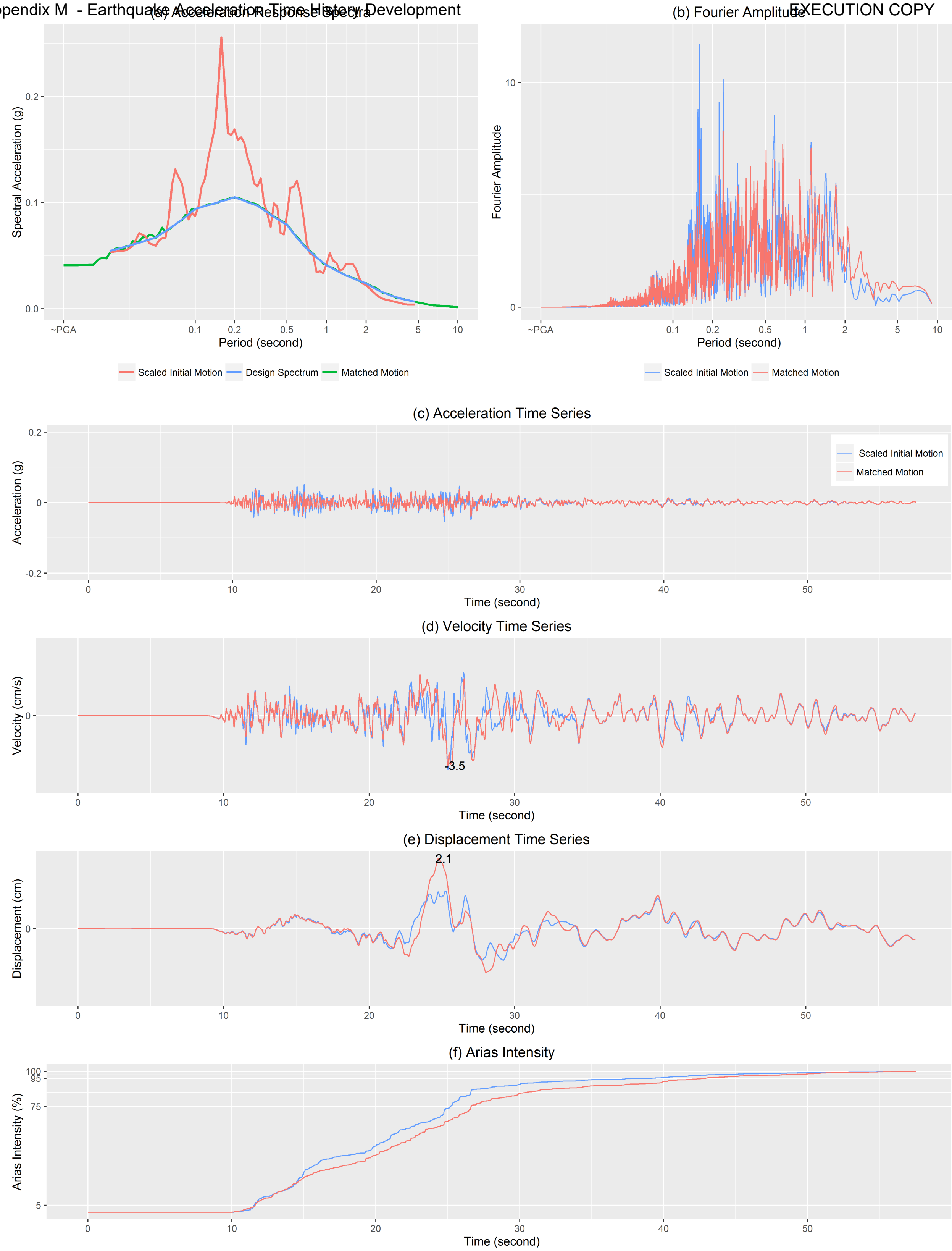
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 215)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A30



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

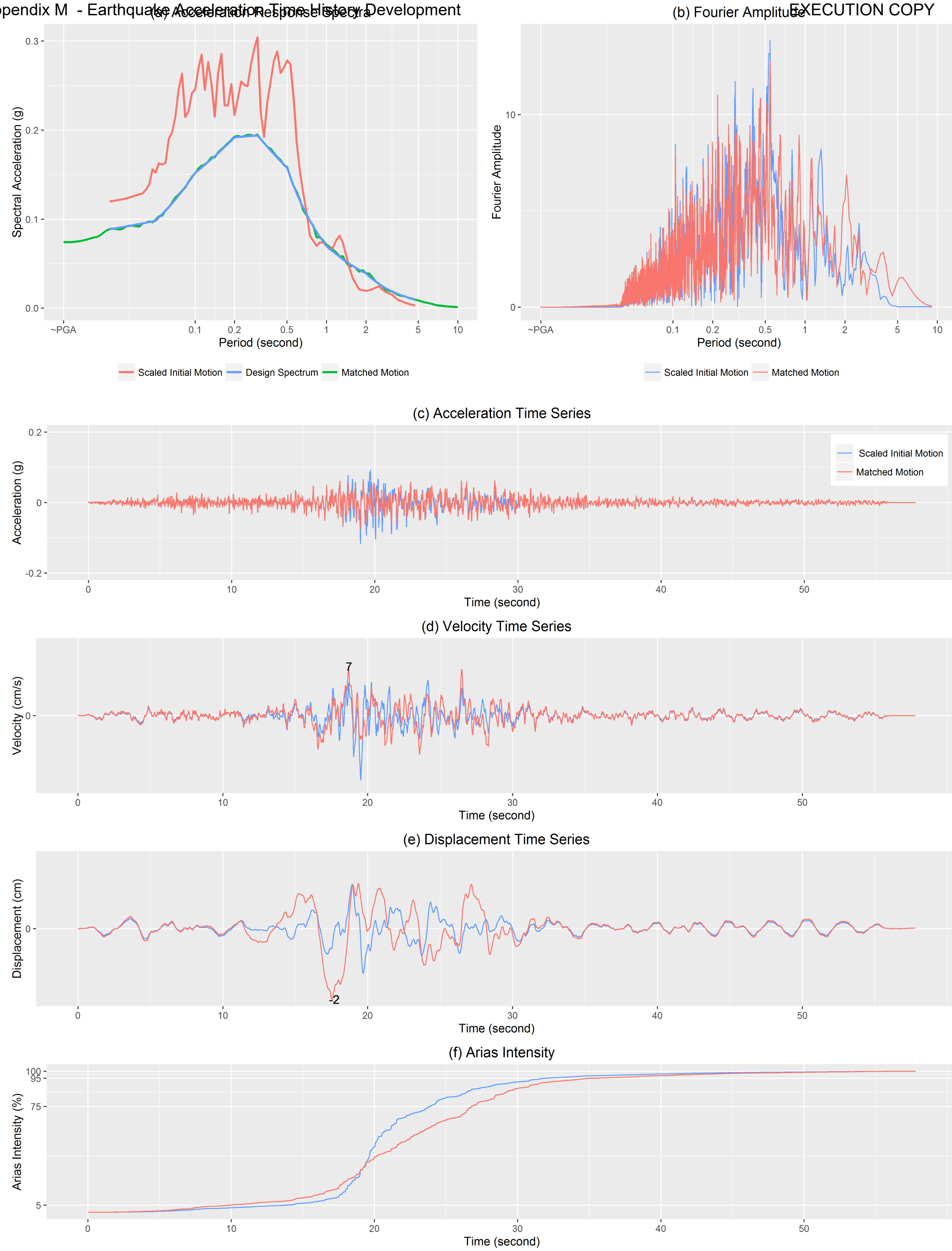
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A31

2018−11−27 16:40:36 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

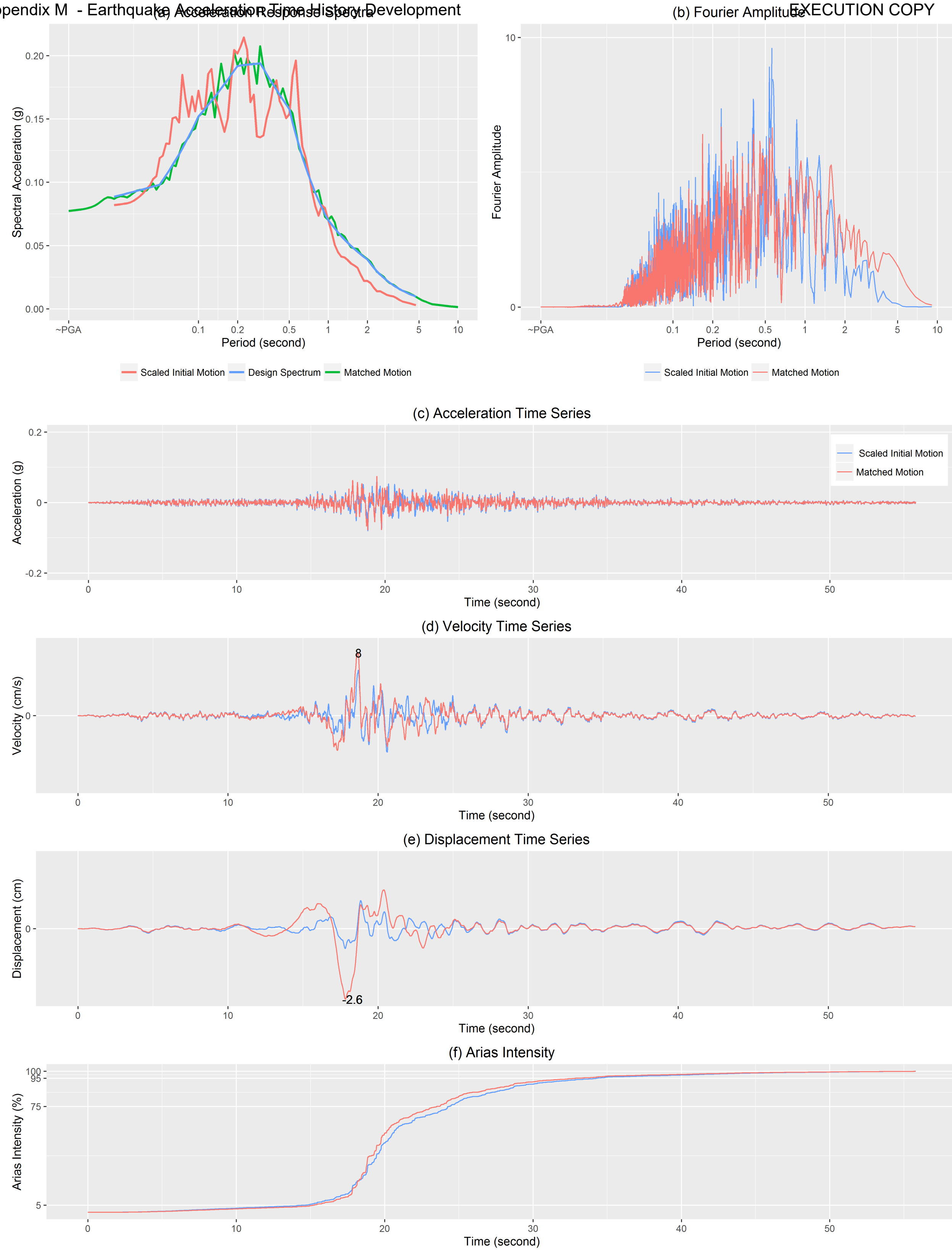
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, L)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A32

2018-11-27 16:40:43 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

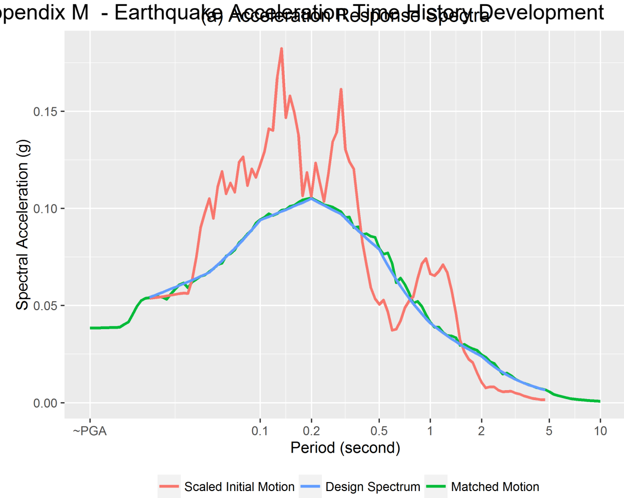
TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, T)

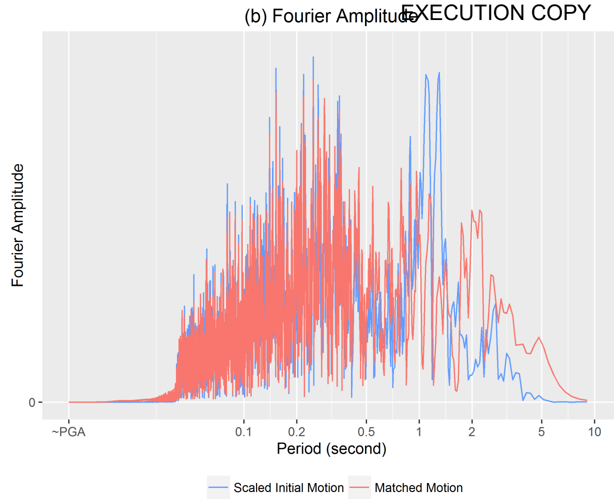
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A33

2018-11-27 16:40:51 FLi

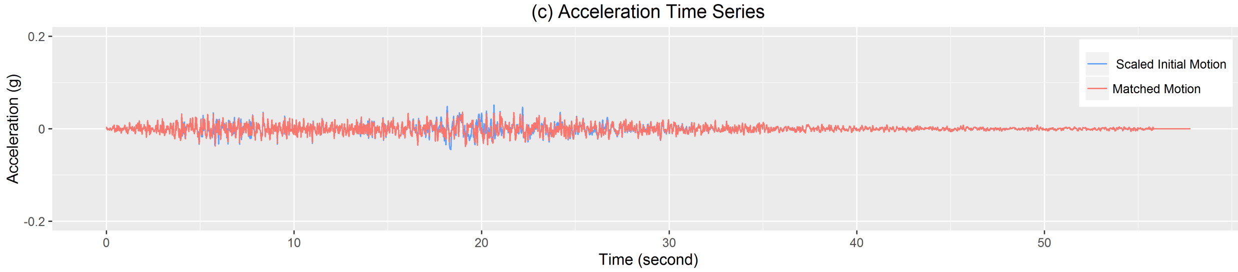
(a) Acceleration Response Spectra



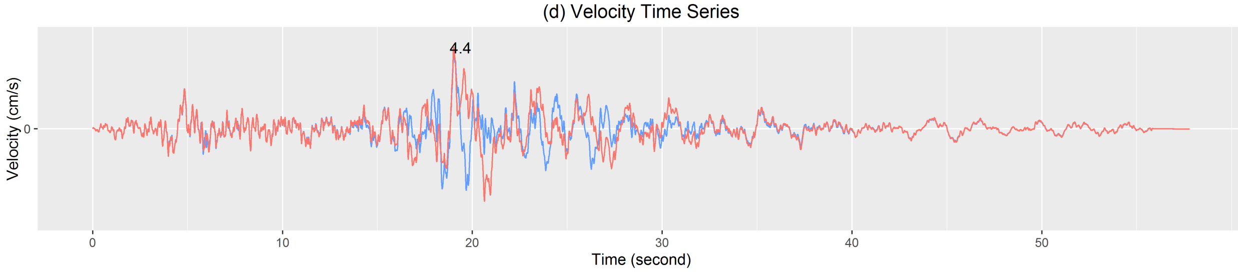
(b) Fourier Amplitude



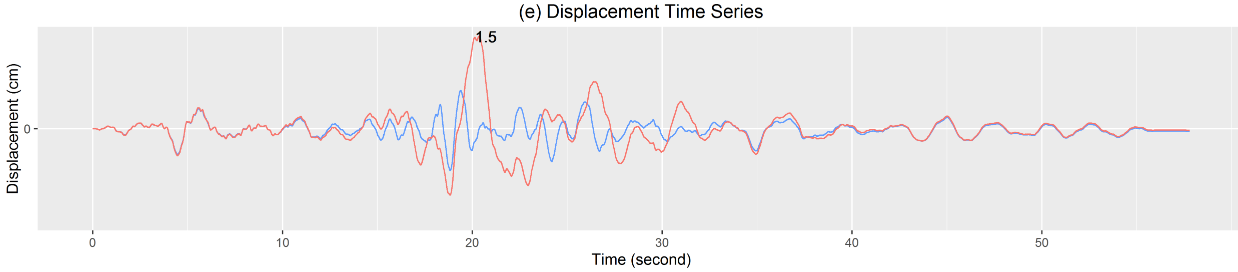
(c) Acceleration Time Series



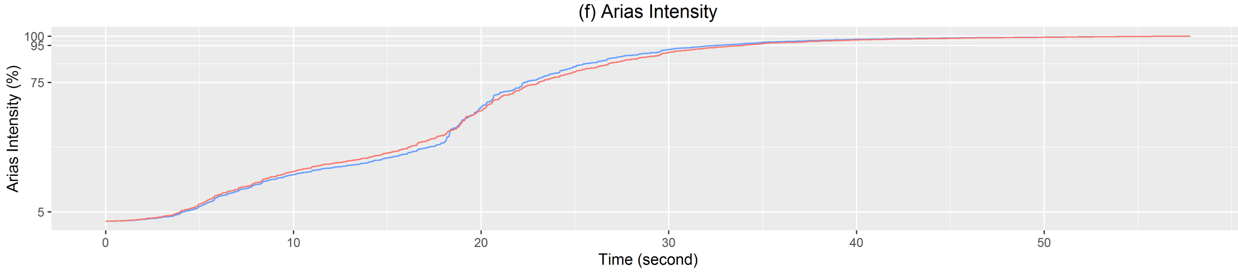
(d) Velocity Time Series



(e) Displacement Time Series



(f) Arias Intensity



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

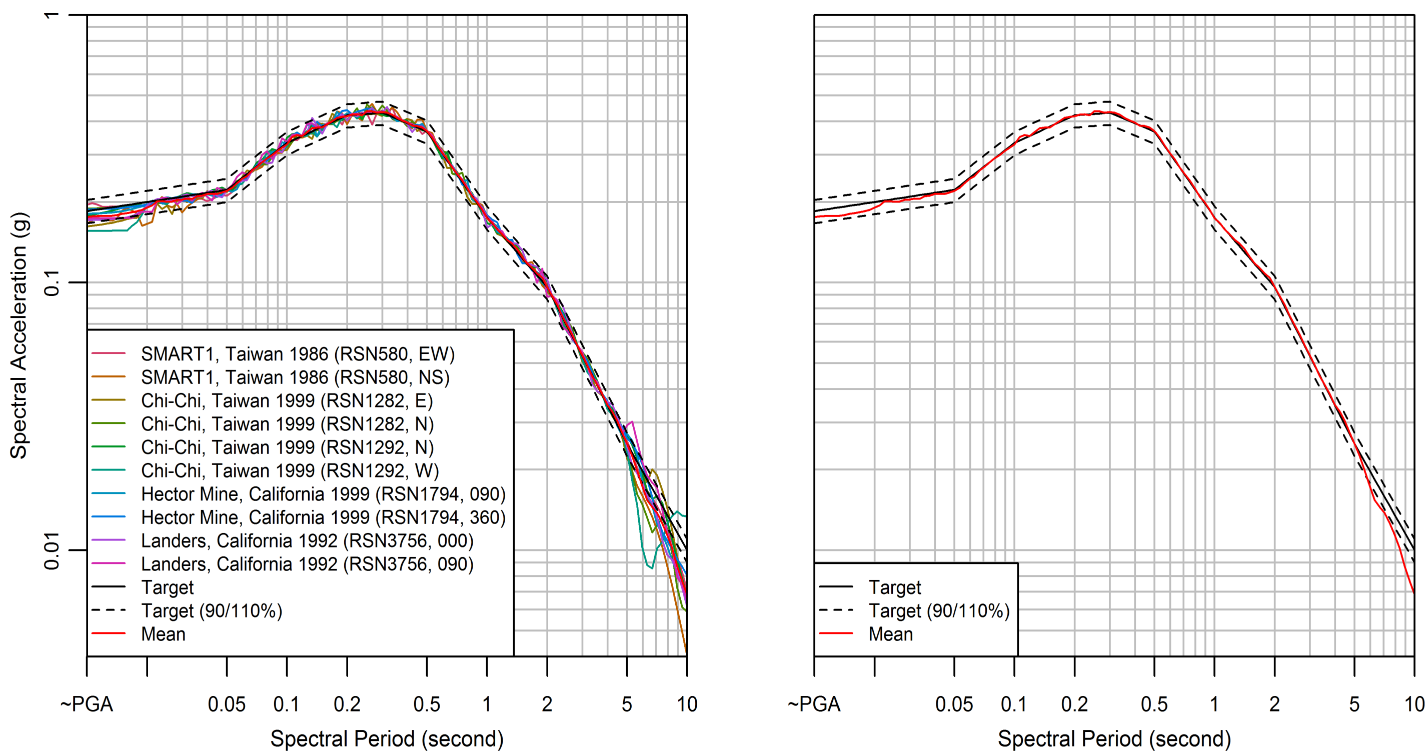
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 100−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A34

2018−11−27 16:40:59 FLi



CLIENT **STANTEC CONSULTANTS INC.**	PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

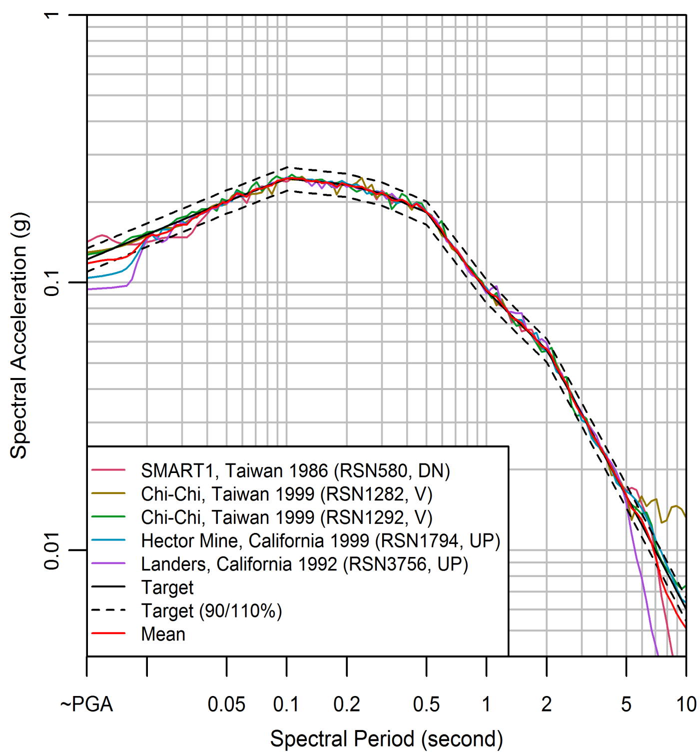
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

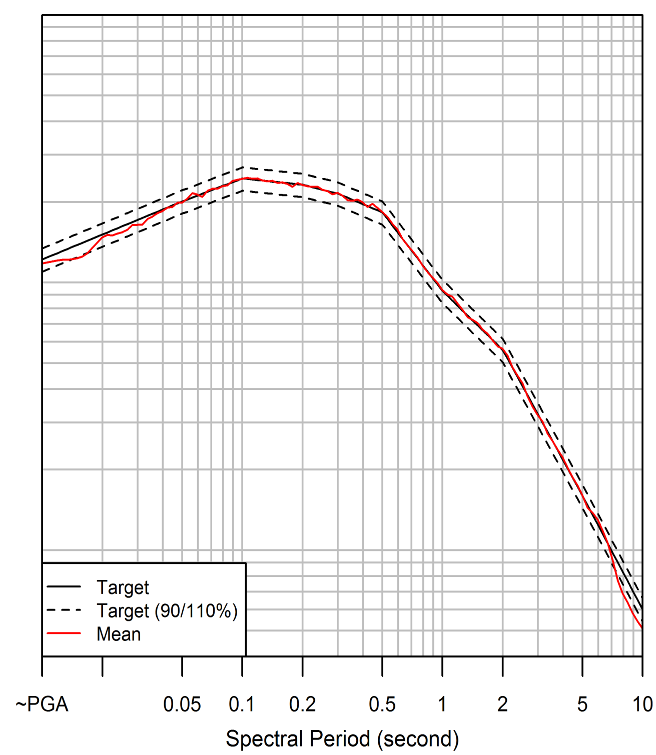
TITLE

COMPARISON OF HORIZONTAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A35

2018−11−27 16:32:48 FLi



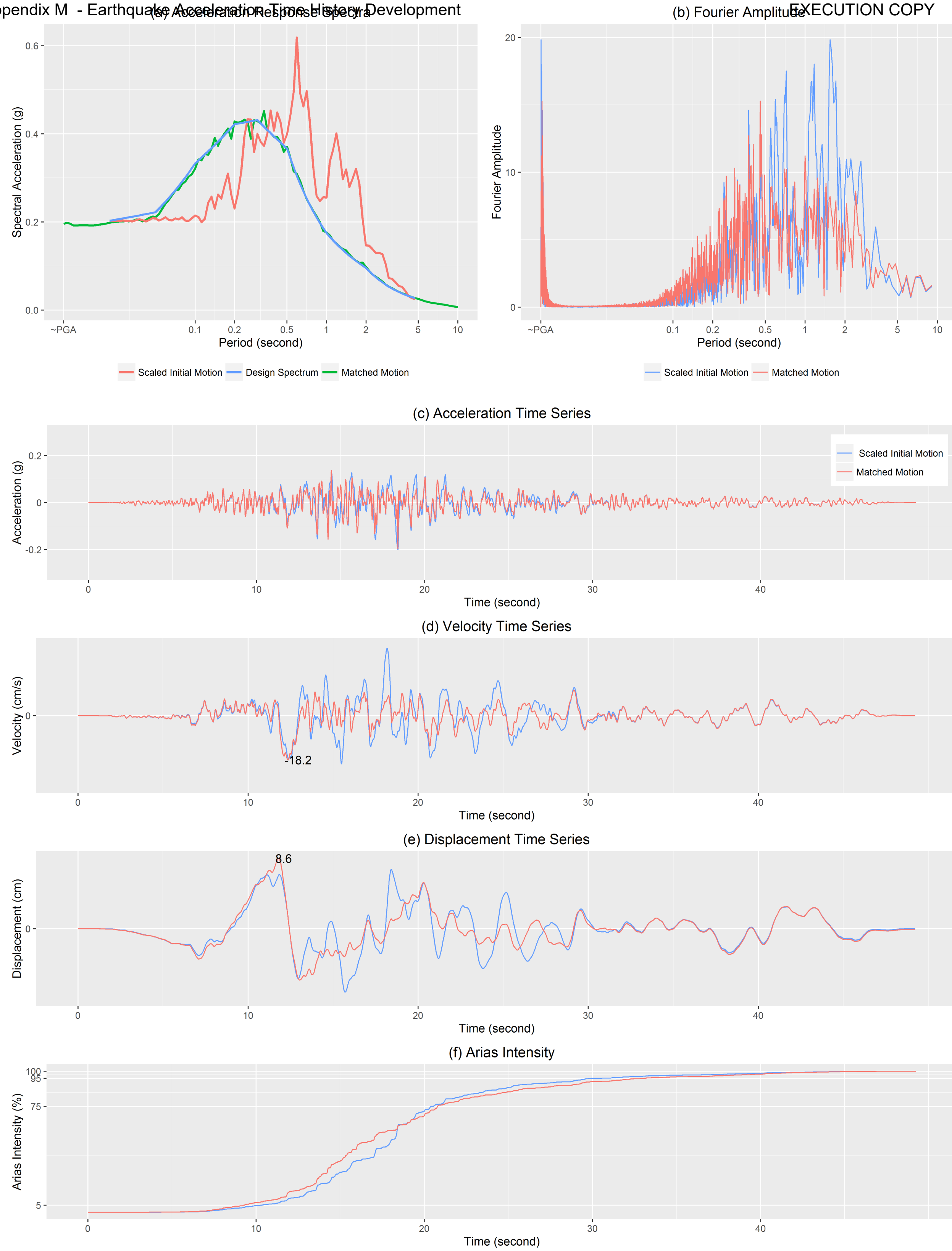


CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT			TITLE
GOLDER	DD/MM/YYYY	11/27/2018	**COMPARISON OF VERTICAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 475−YEAR RETURN PERIOD**
	PREPARED	AR	
	DESIGN	AR	
	REVIEW	FL	
	APPROVED	AH	

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A36

2018-11-27 16:32:51 FL



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

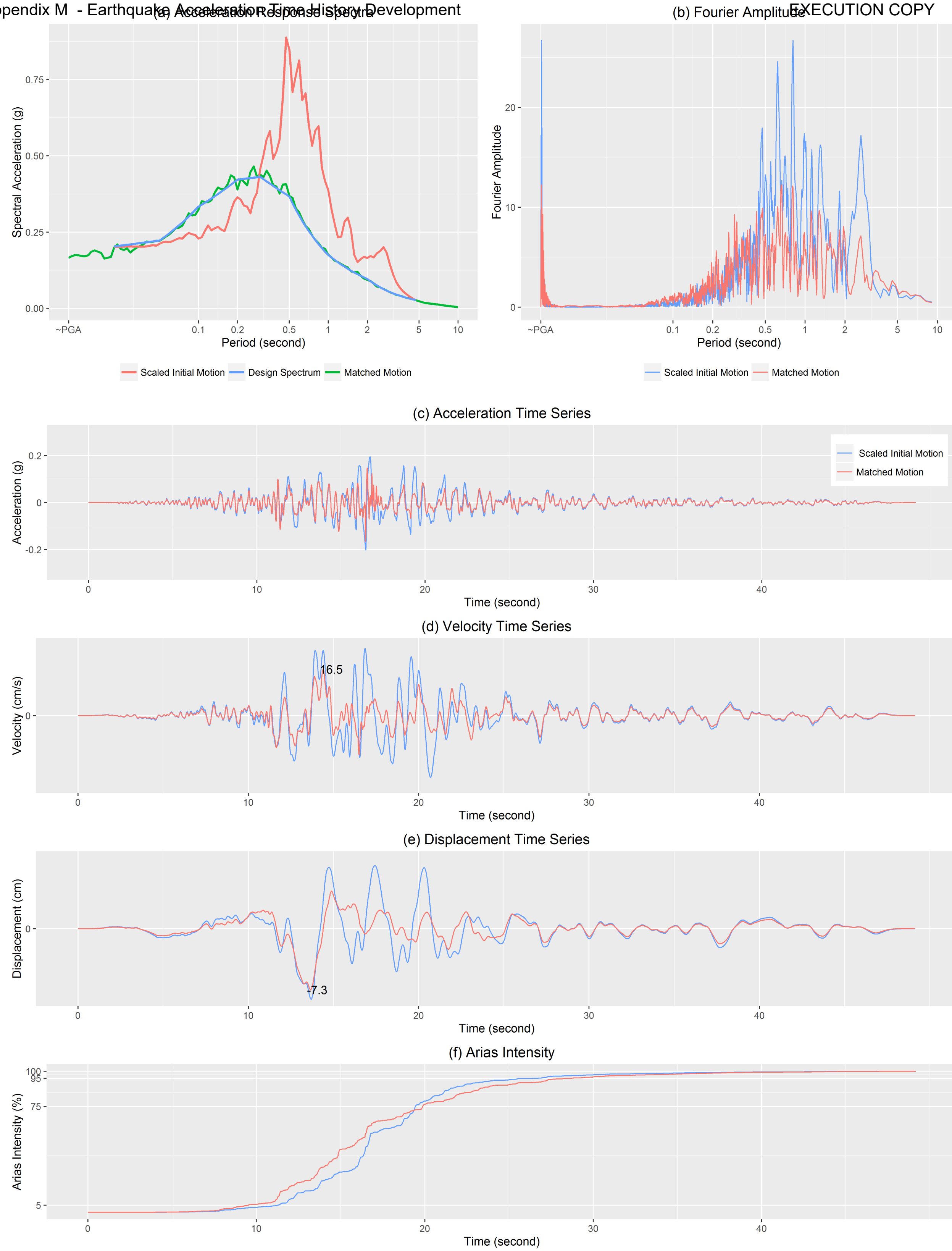
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A37

2018-11-27 16:32:53 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

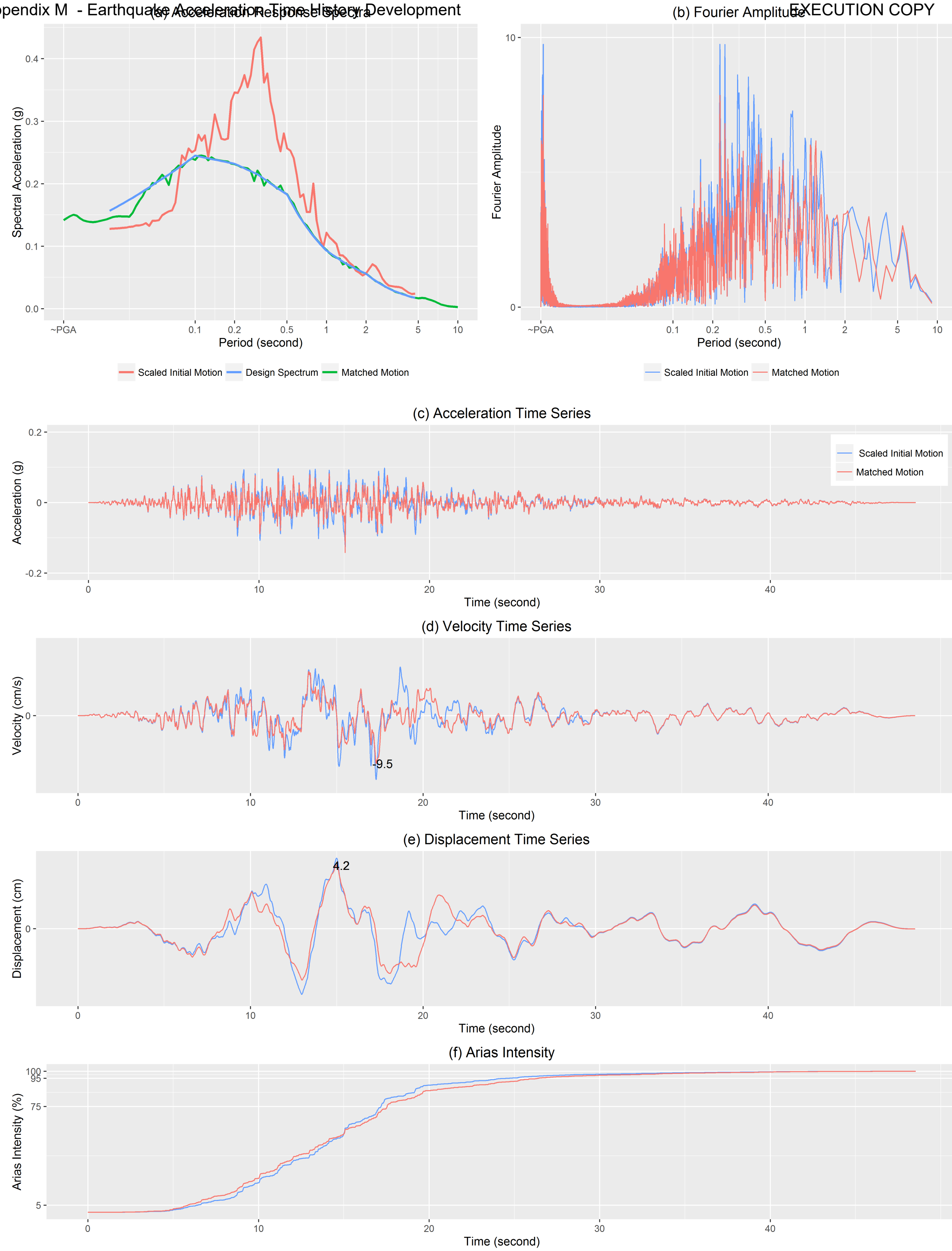
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A38

2018-11-27 16:33:01 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

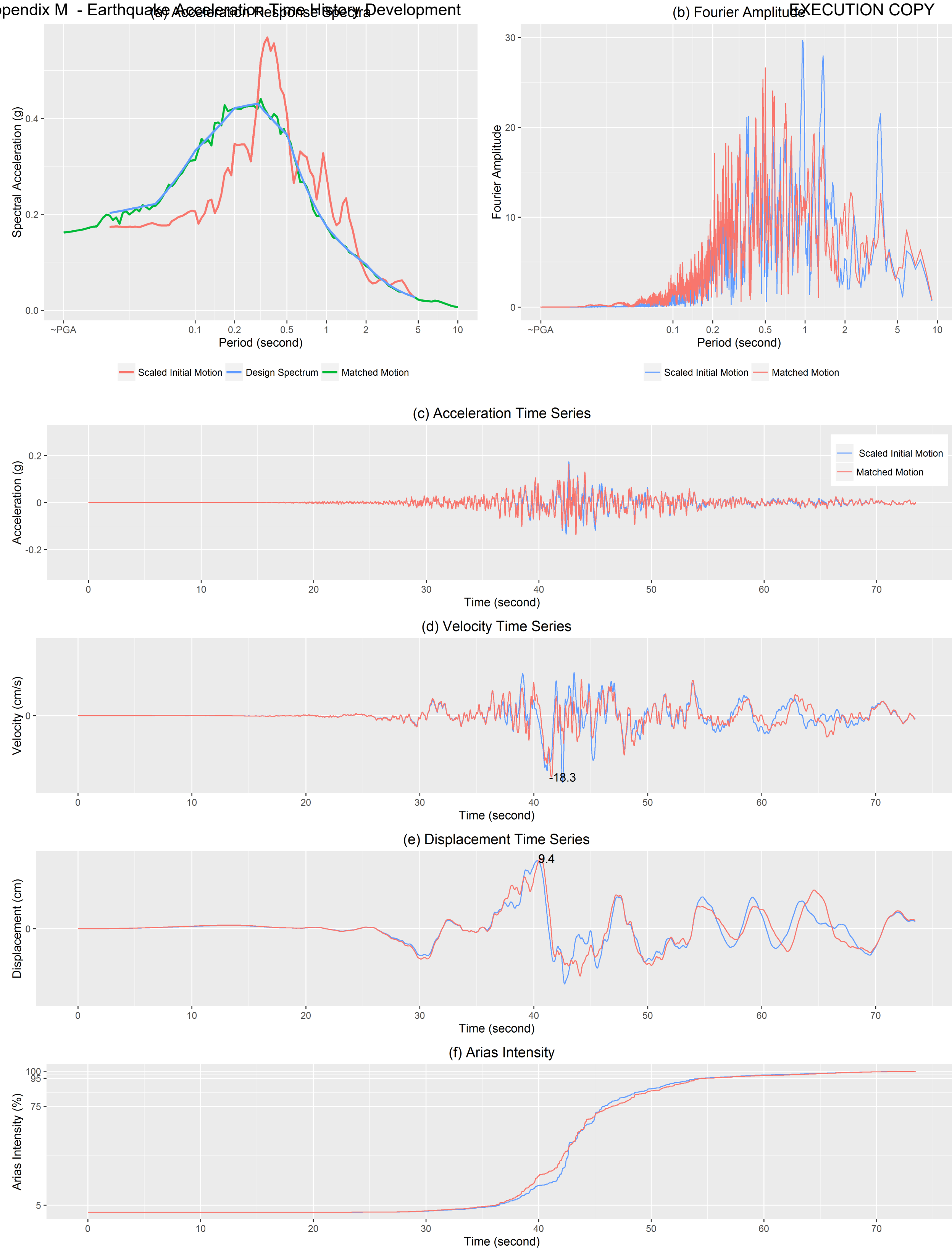
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, DN)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A39

2018-11-27 16:33:10 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

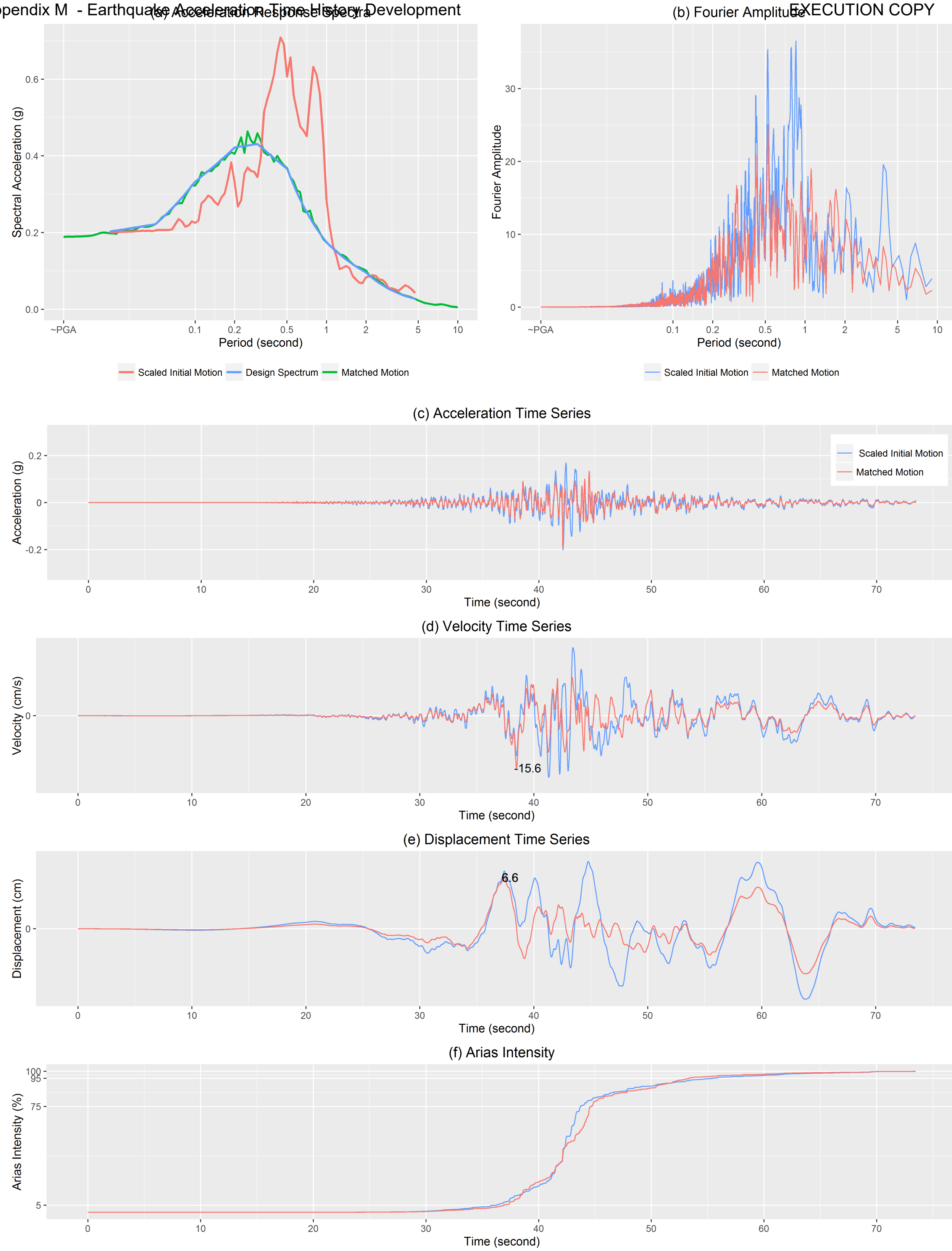
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A40

2018-11-27 16:33:18 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

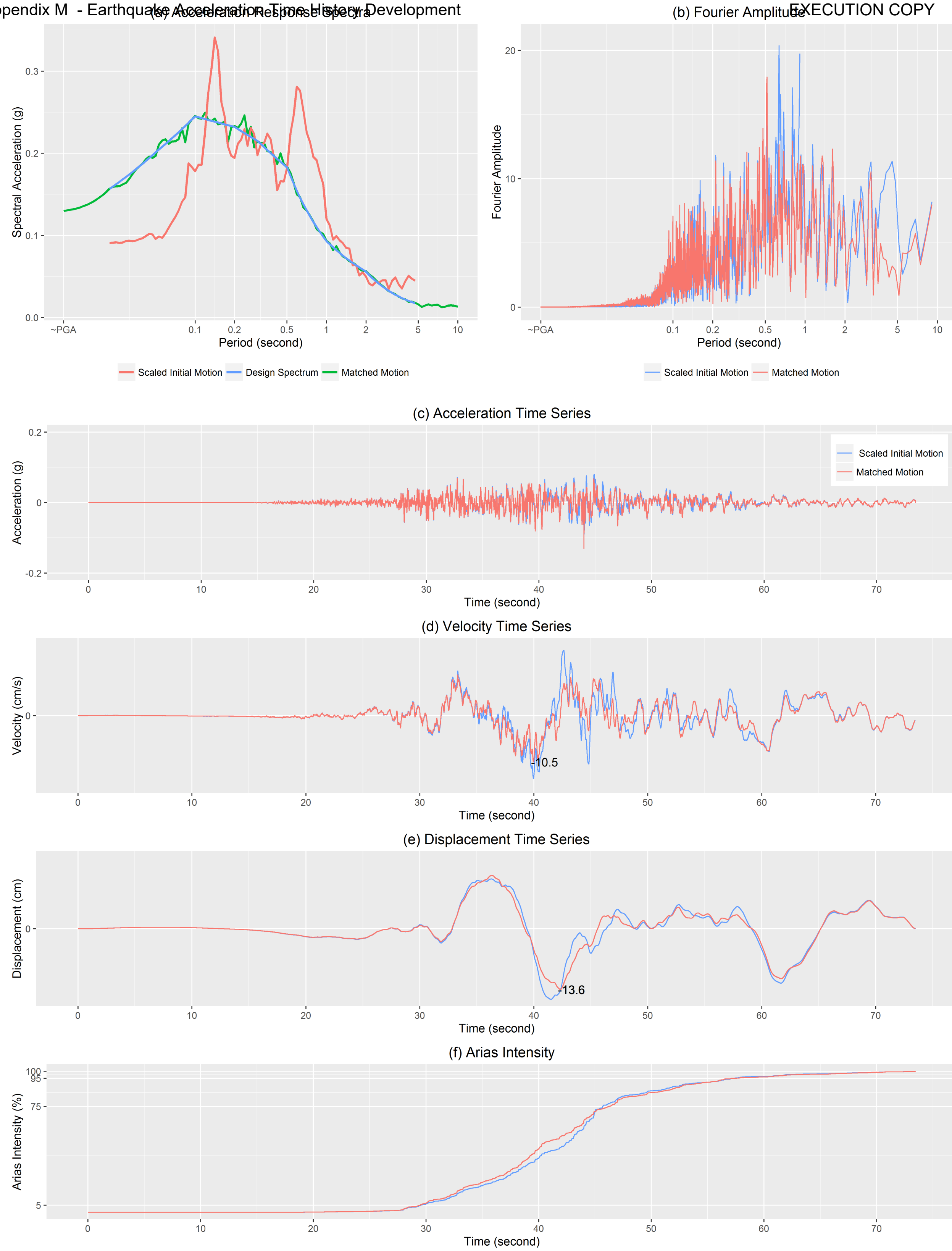
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A41

2018-11-27 16:33:26 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

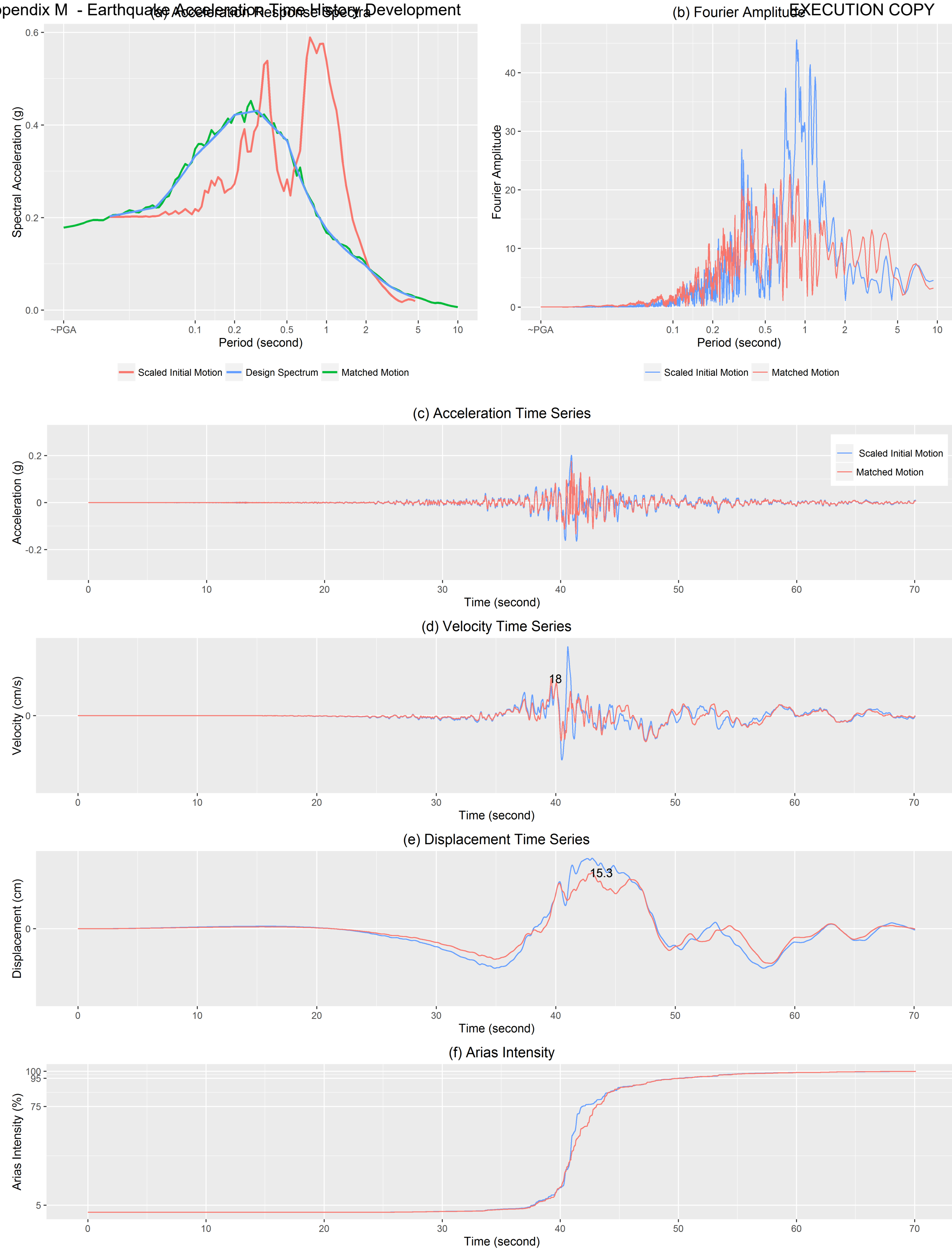
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A42

2018-11-27 16:33:34 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

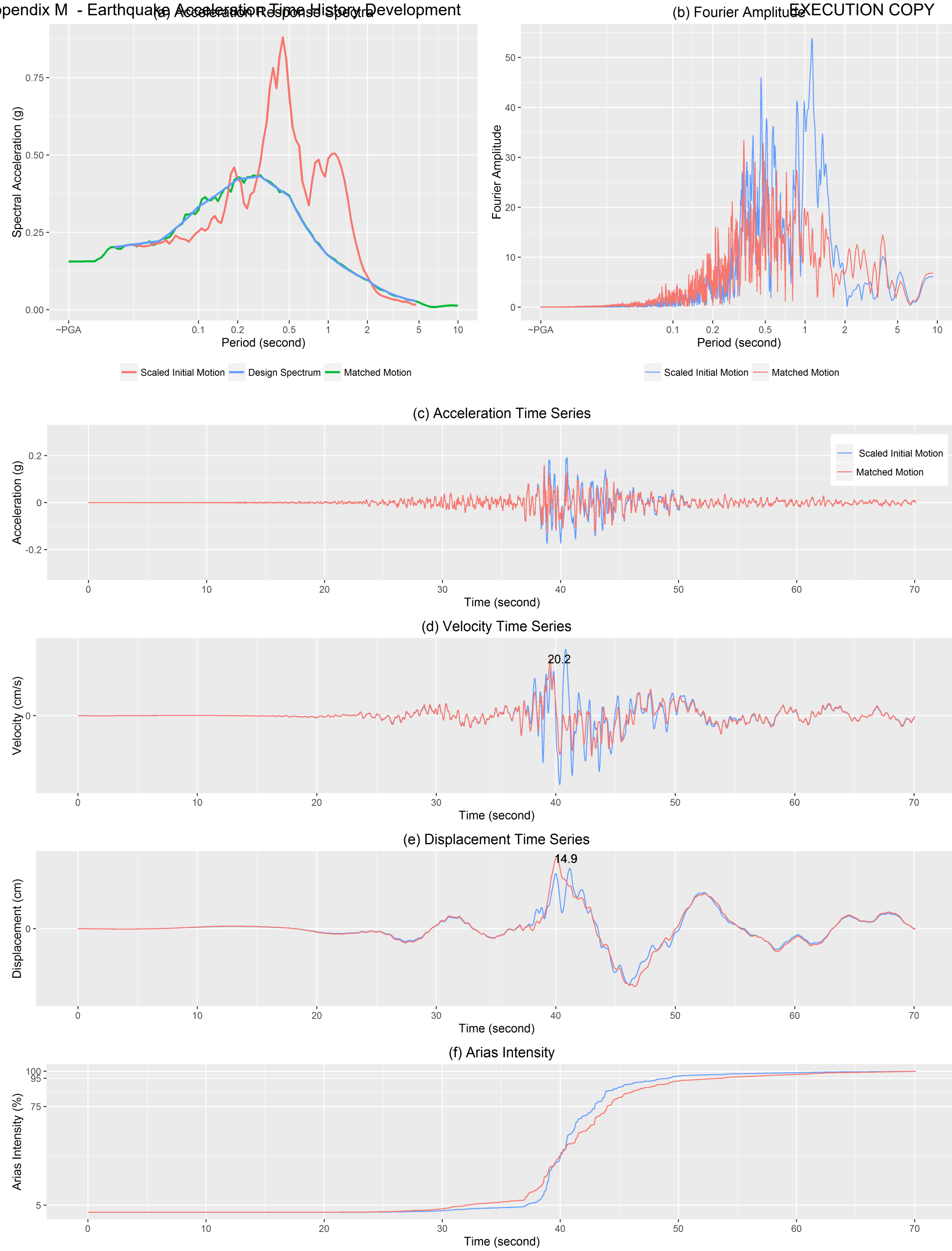
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A43

2018−11−27 16:33:42 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

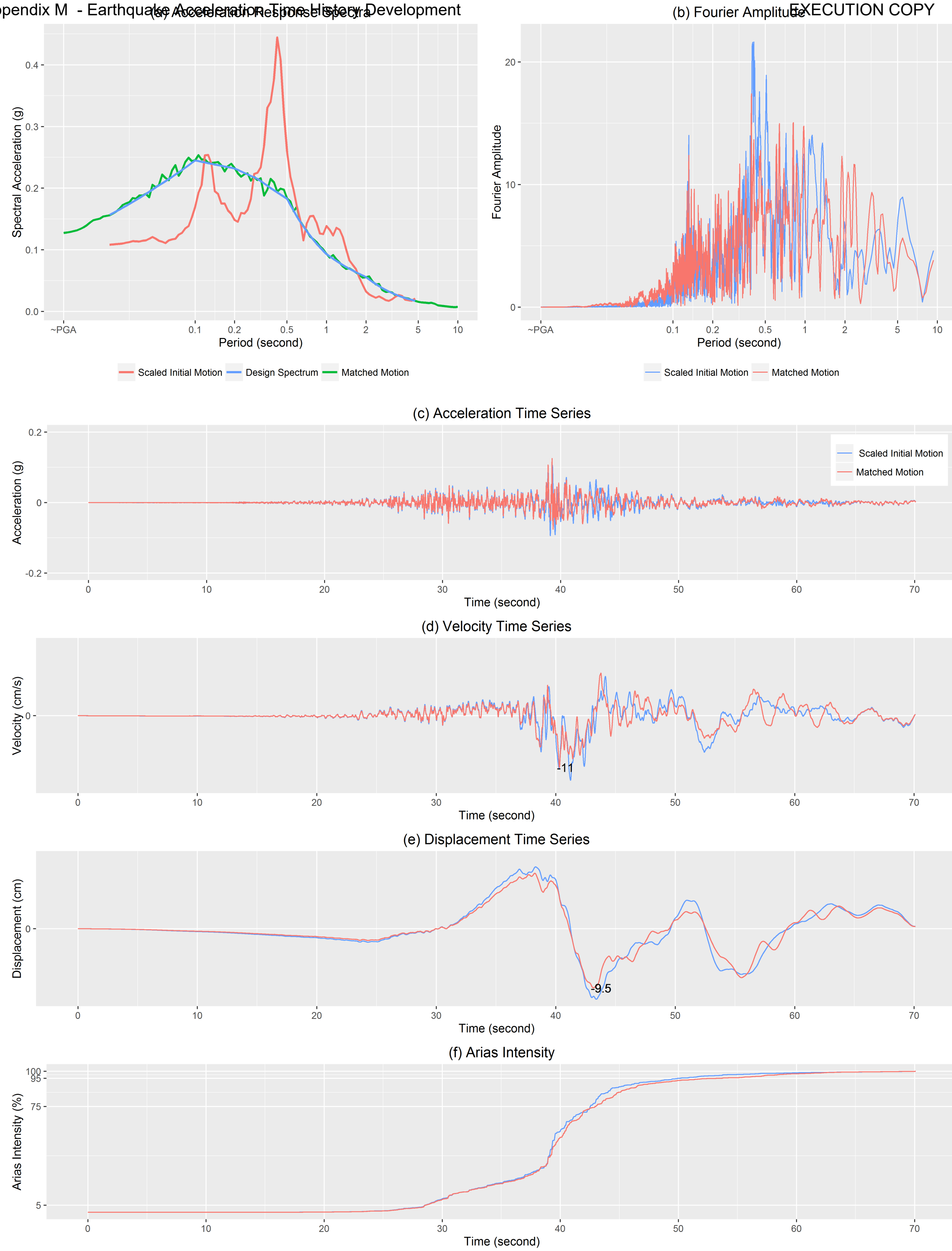
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, W)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A44

2018-11-27 16:33:50 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

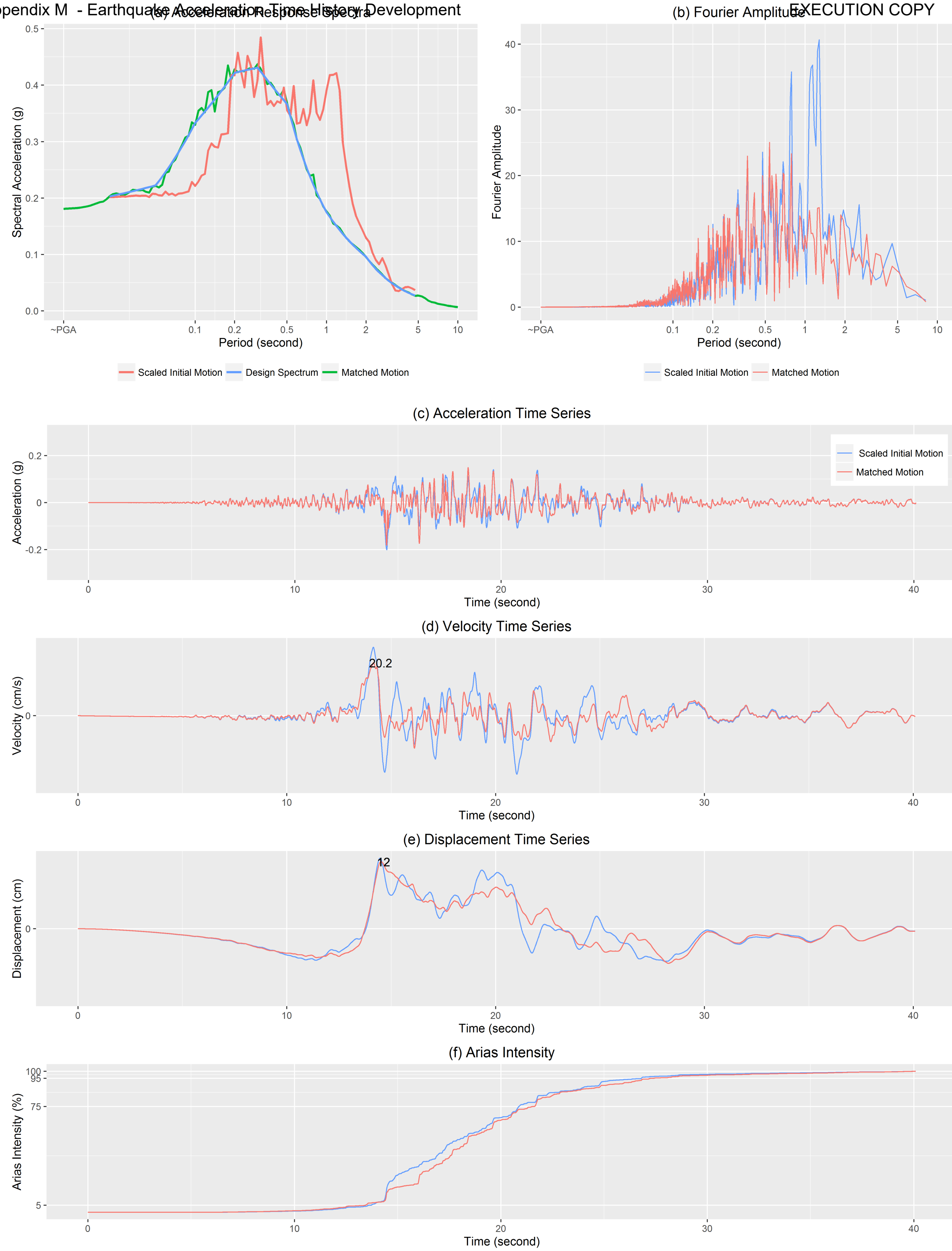
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A45

2018-11-27 16:33:58 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

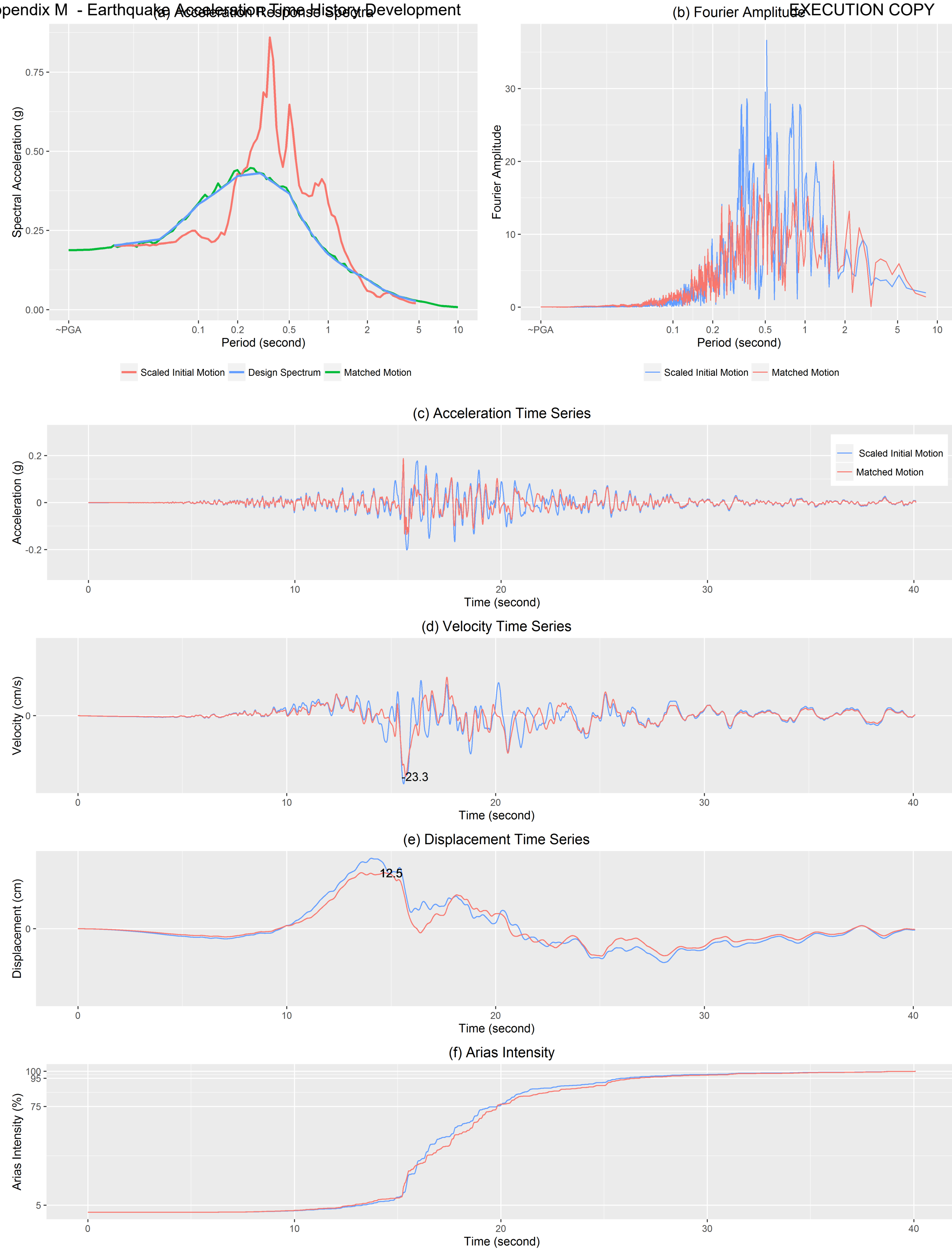
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A46

2018−11−27 16:34:06 FL



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

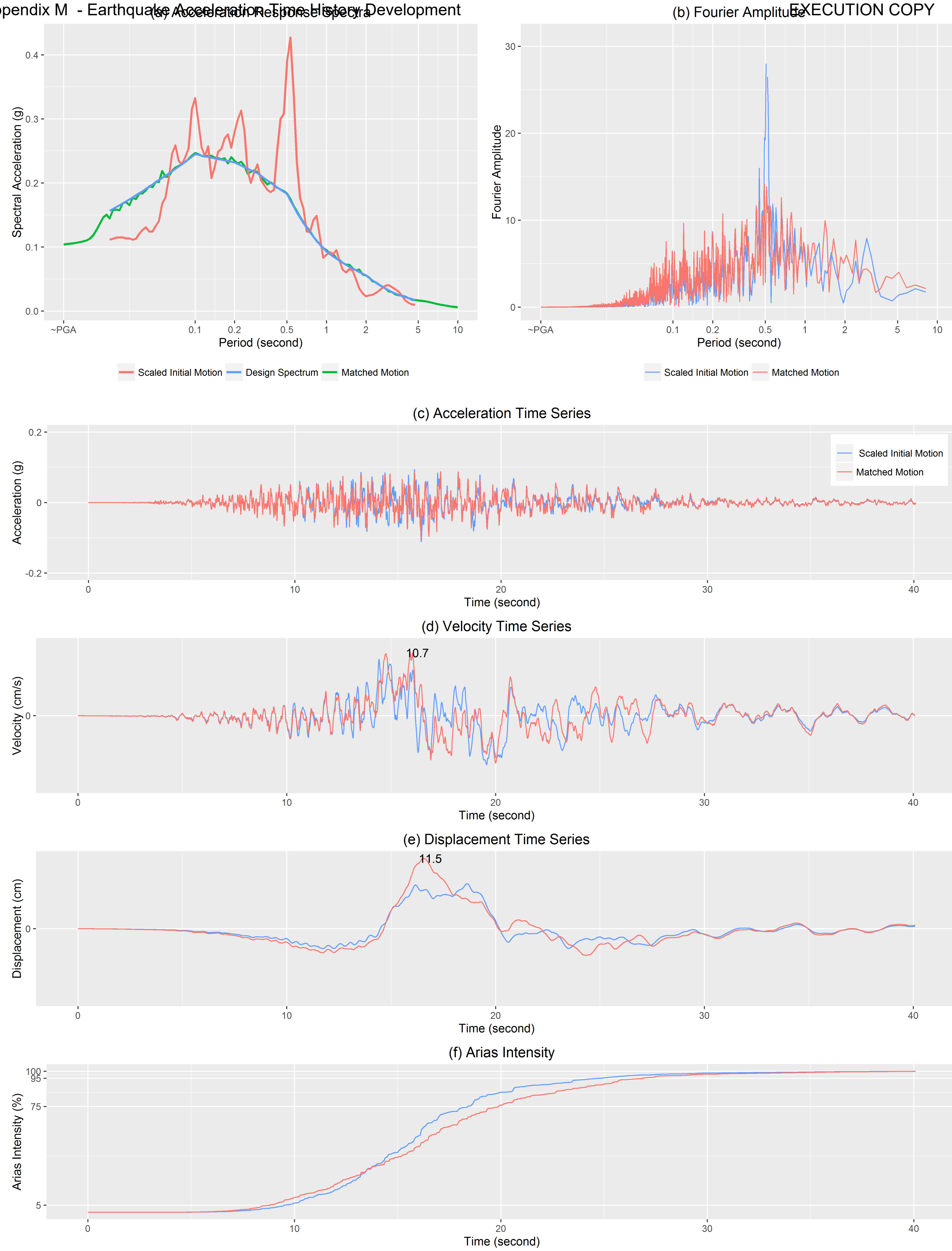
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 360)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A47

2018-11-27 16:34:13 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

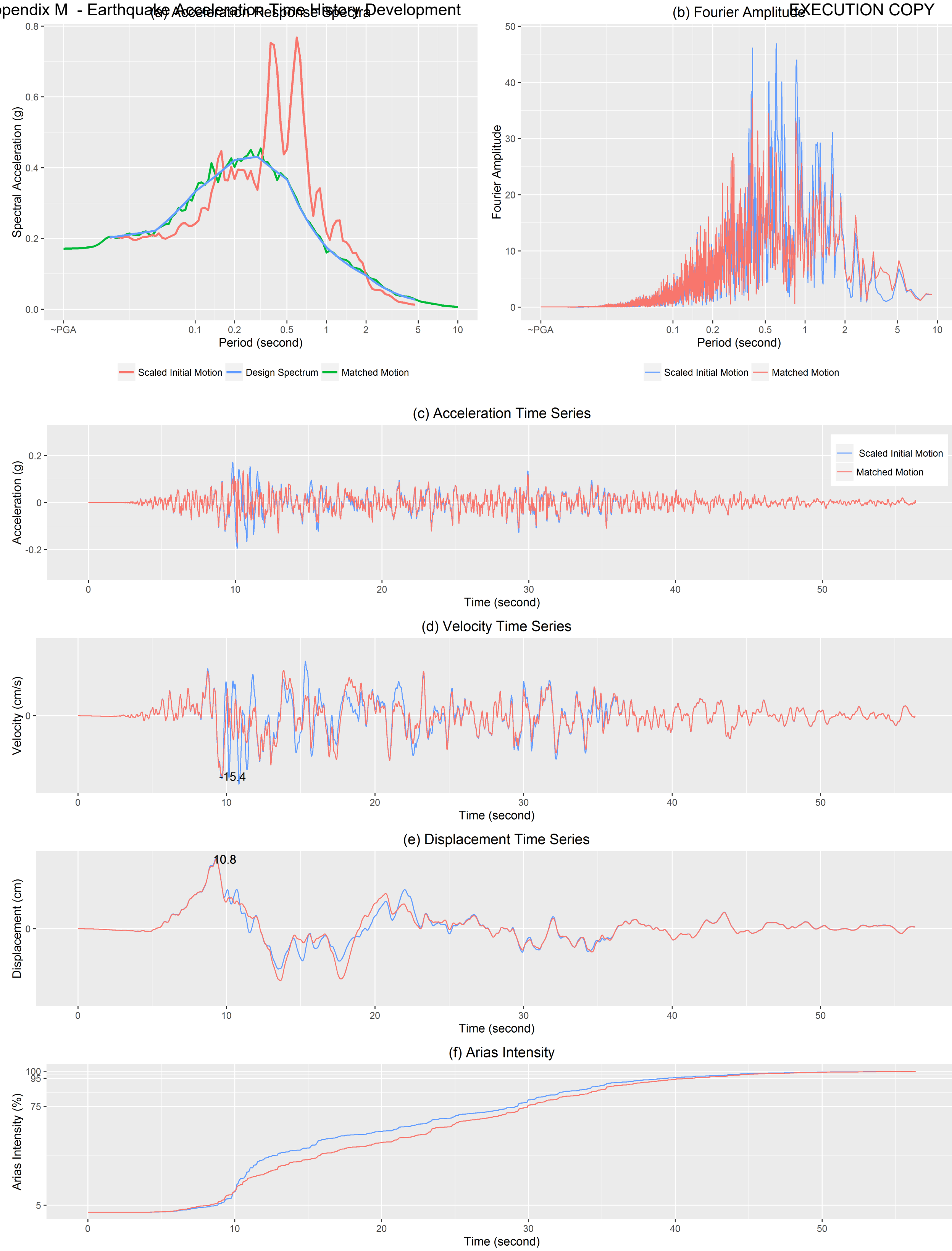
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A48



CLIENT **STANTEC CONSULTANTS INC.**	PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

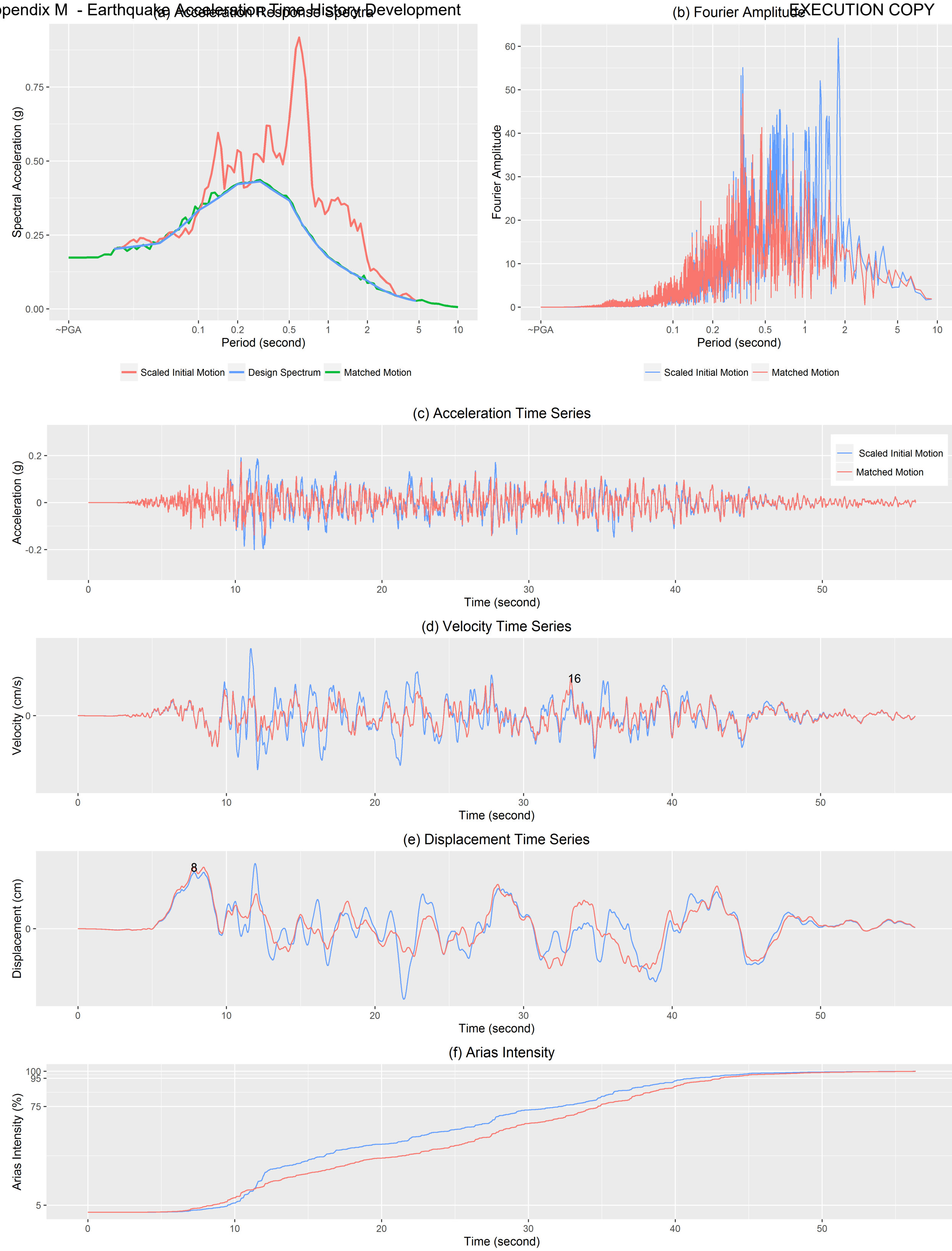
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 0)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A49

2018−11−27 16:34:29 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

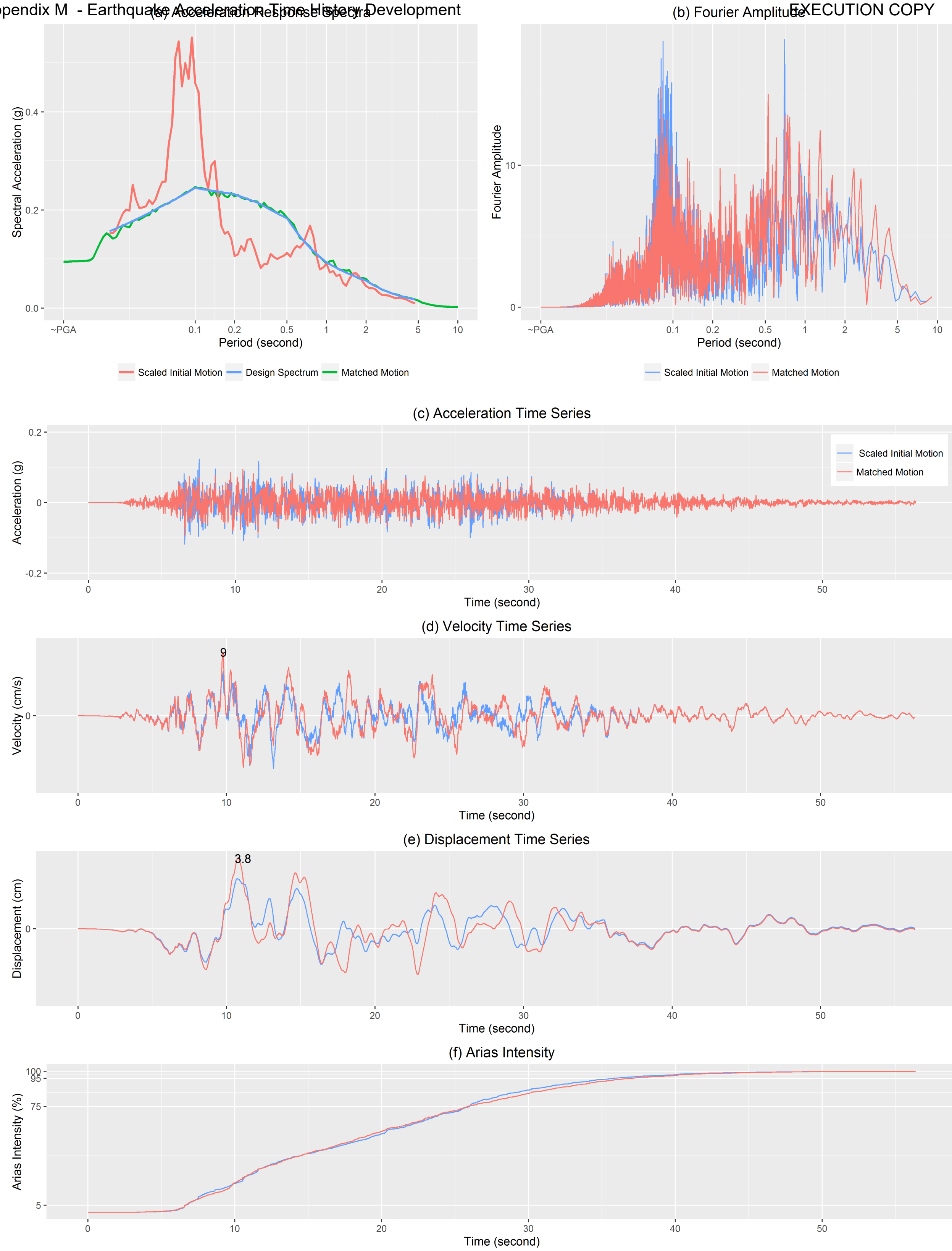
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A50

2018-11-27 16:34:37 FLi



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

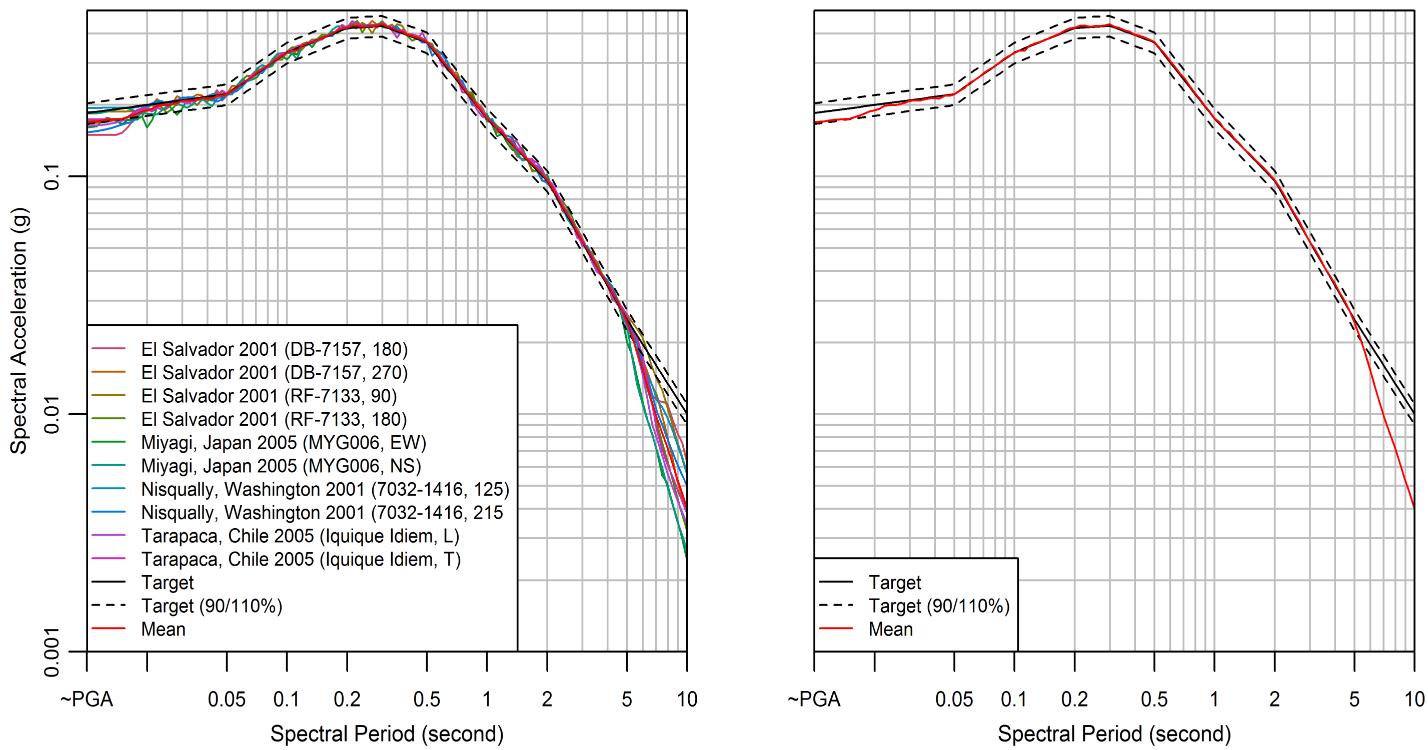
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A51

2018-11-27 16:34:45 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

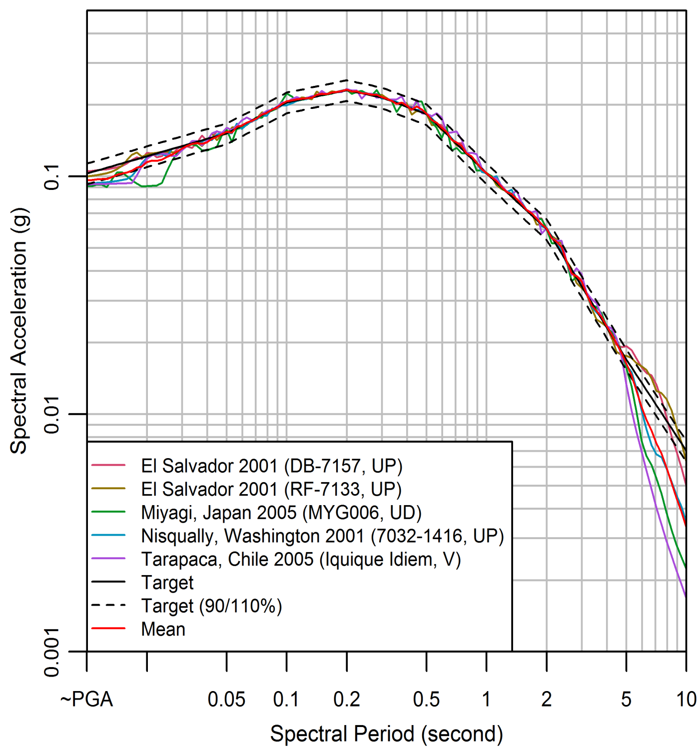
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

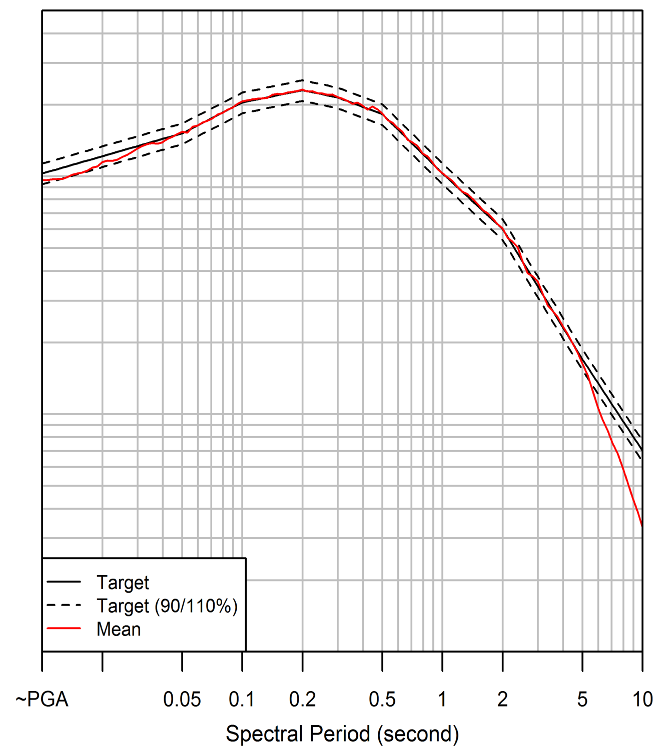
TITLE

COMPARISON OF HORIZONTAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A52

2018−11−27 16:34:52 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

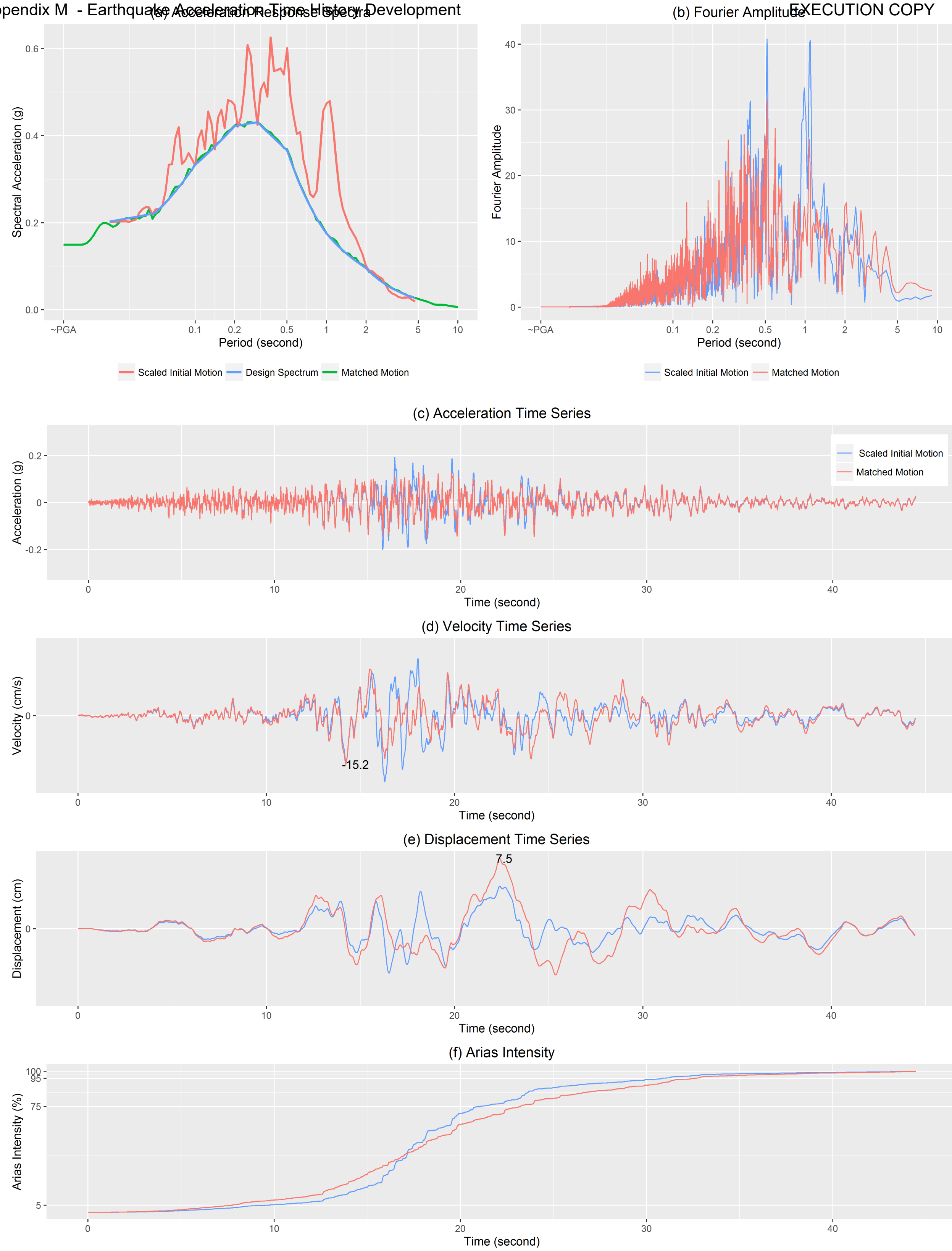
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF VERTICAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A53

2018-11-27 16:34:55 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

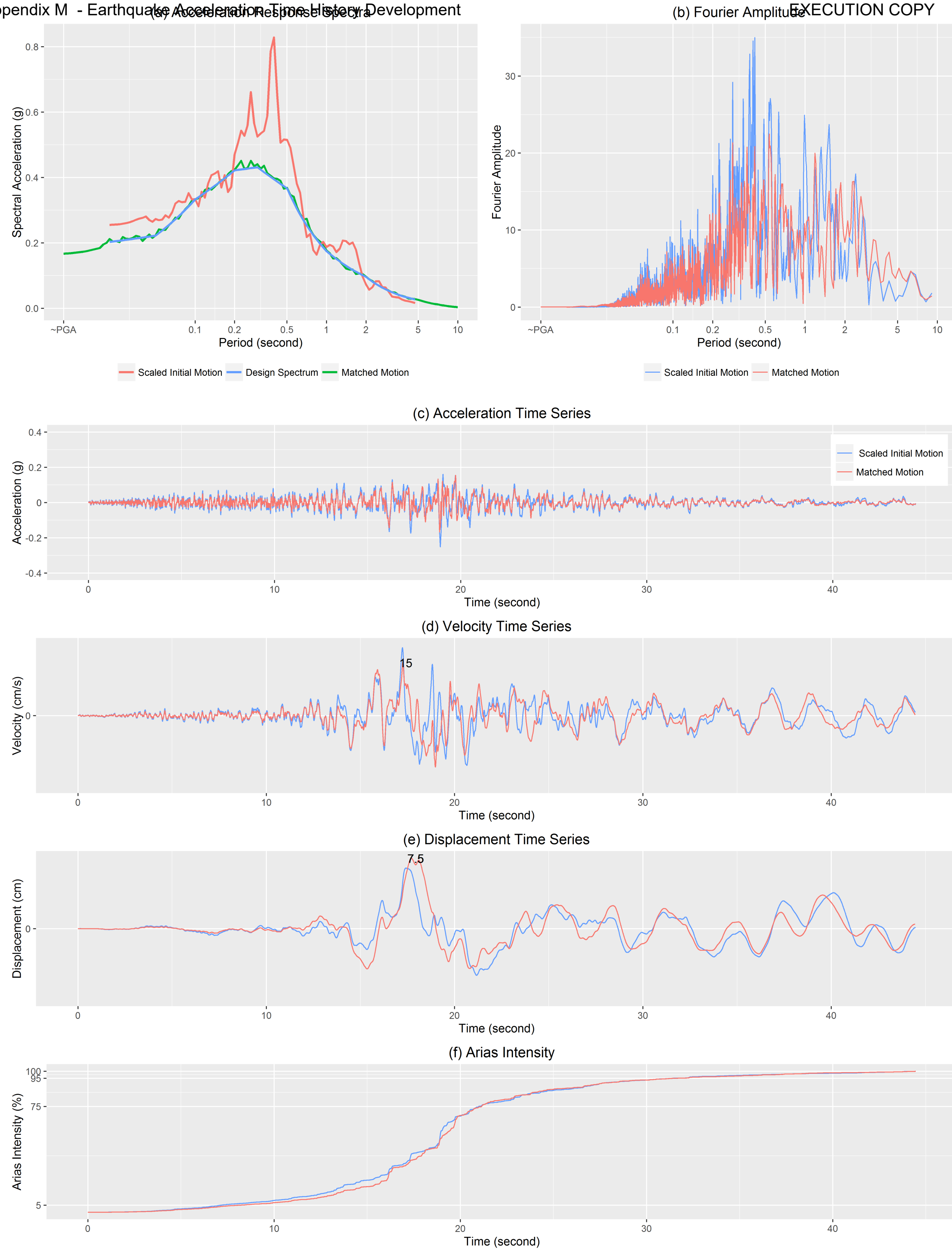
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 180)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A54

2018−11−27 16:34:58 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

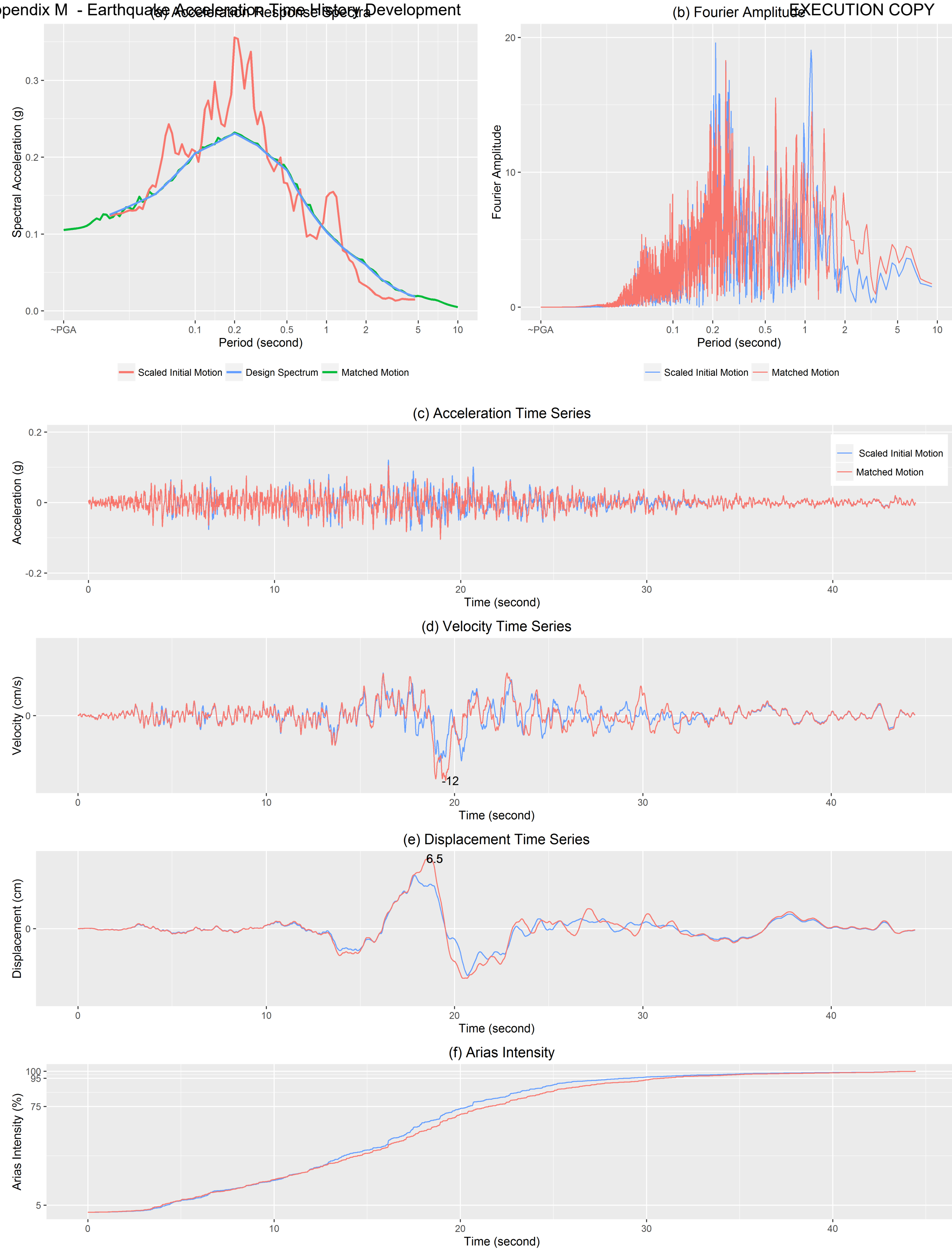
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 270)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A55



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

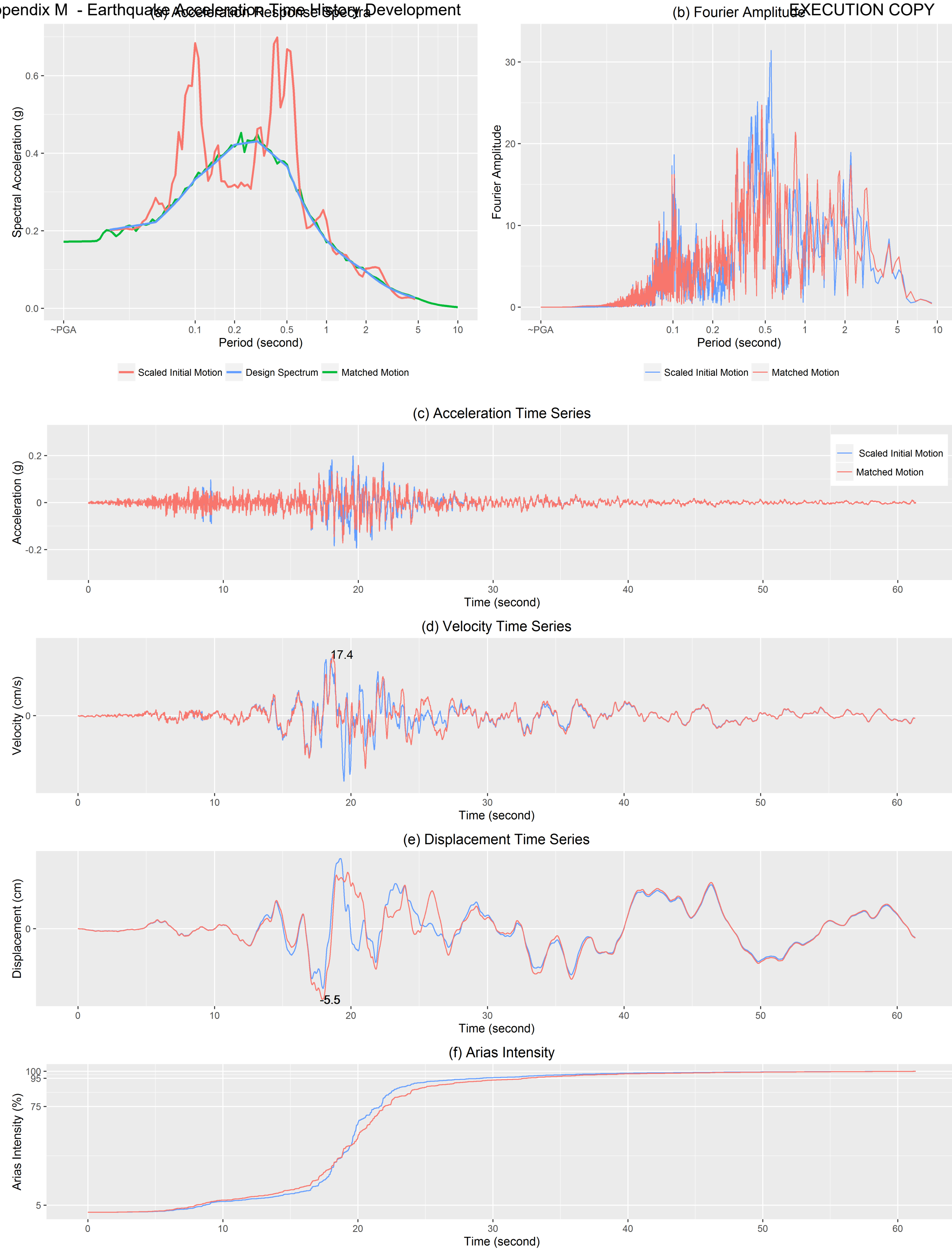
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A56

2018-11-27 16:35:13 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

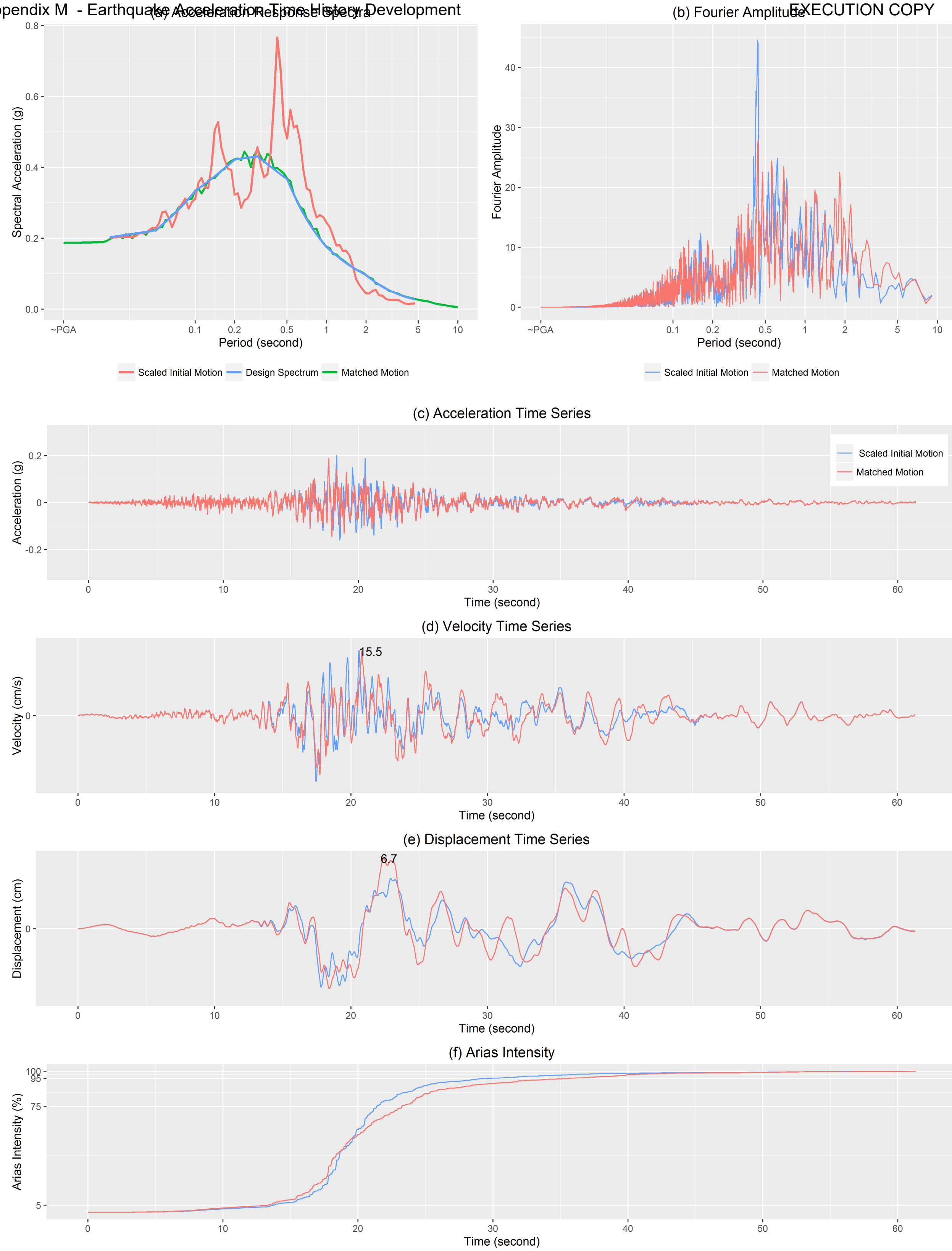
CONSULTANT		
GOLDER	DD/MM/YYYY	11/27/2018
	PREPARED	AR
	DESIGN	AR
	REVIEW	FL
	APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 180)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A57

2018-11-27 16:35:21 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

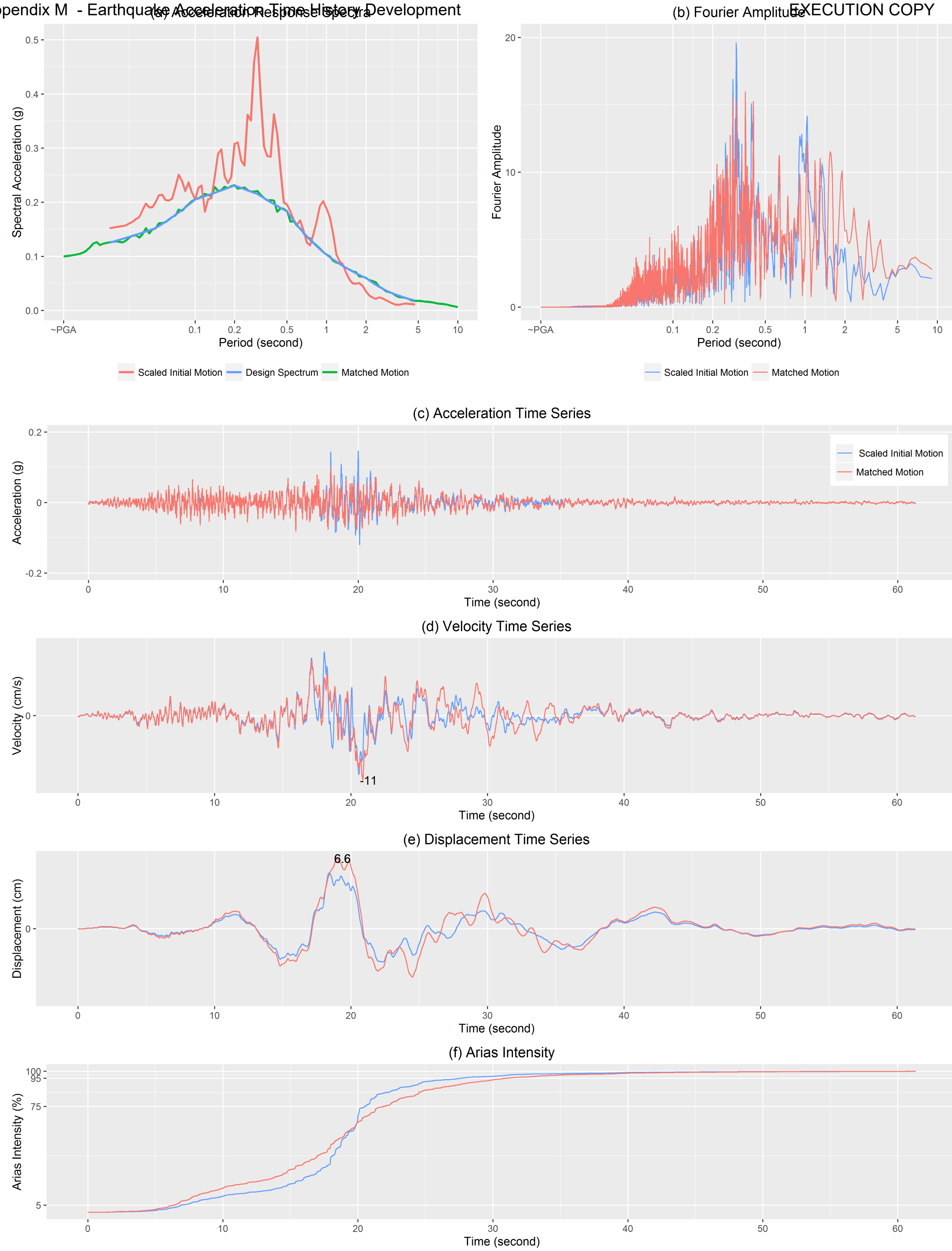
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A58

2018−11−27 16:35:29 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

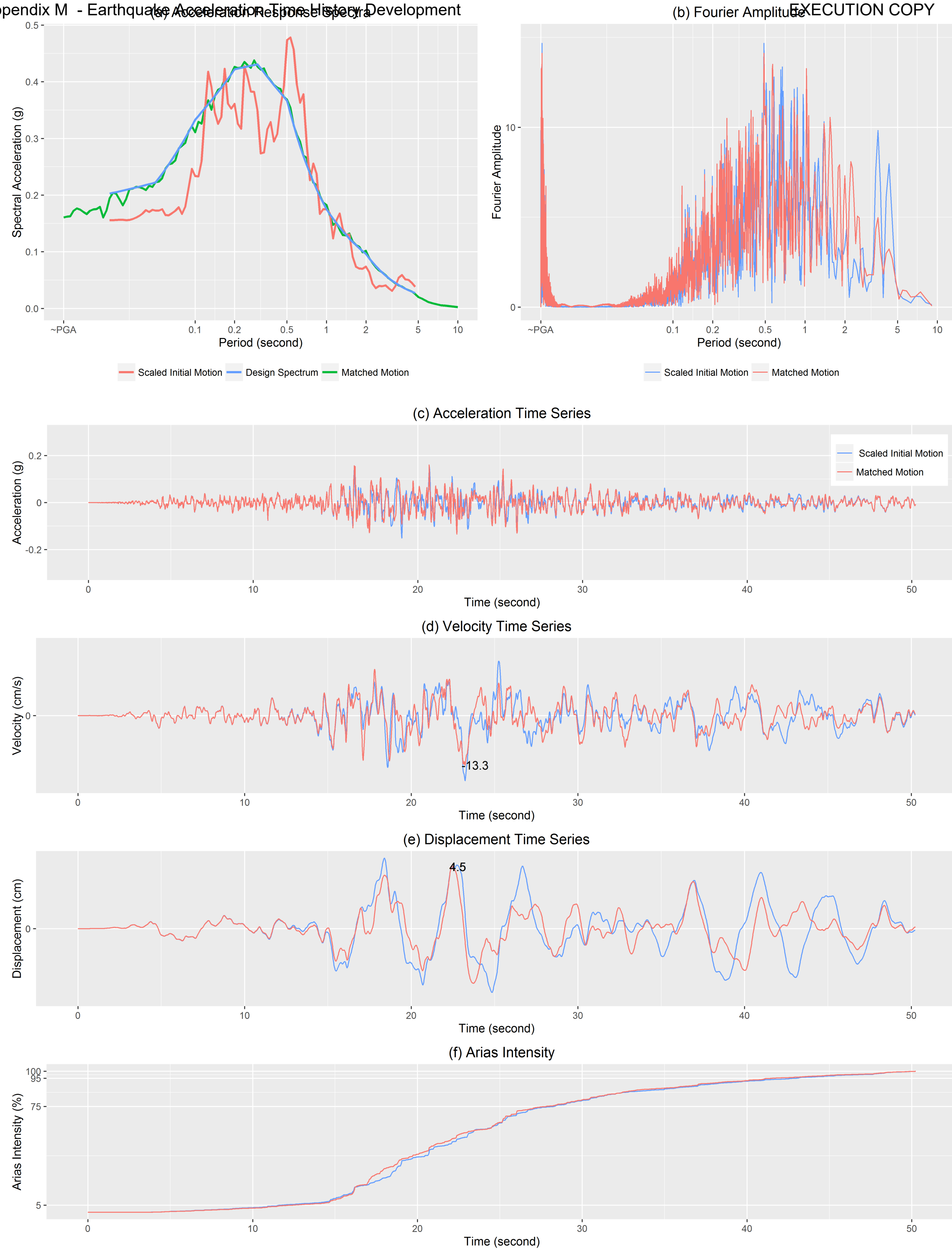
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A59

2018-11-27 16:35:37 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

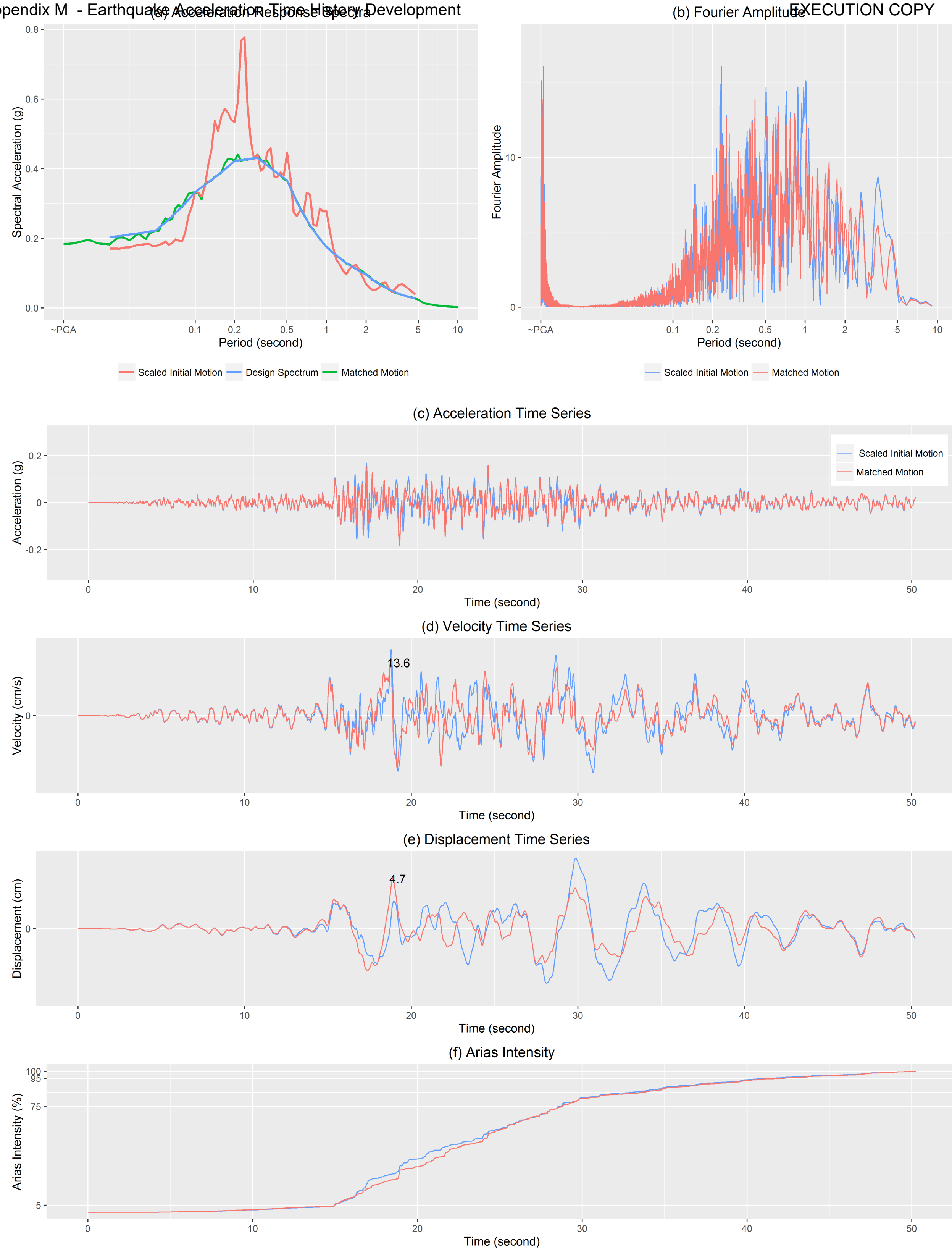
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A60



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

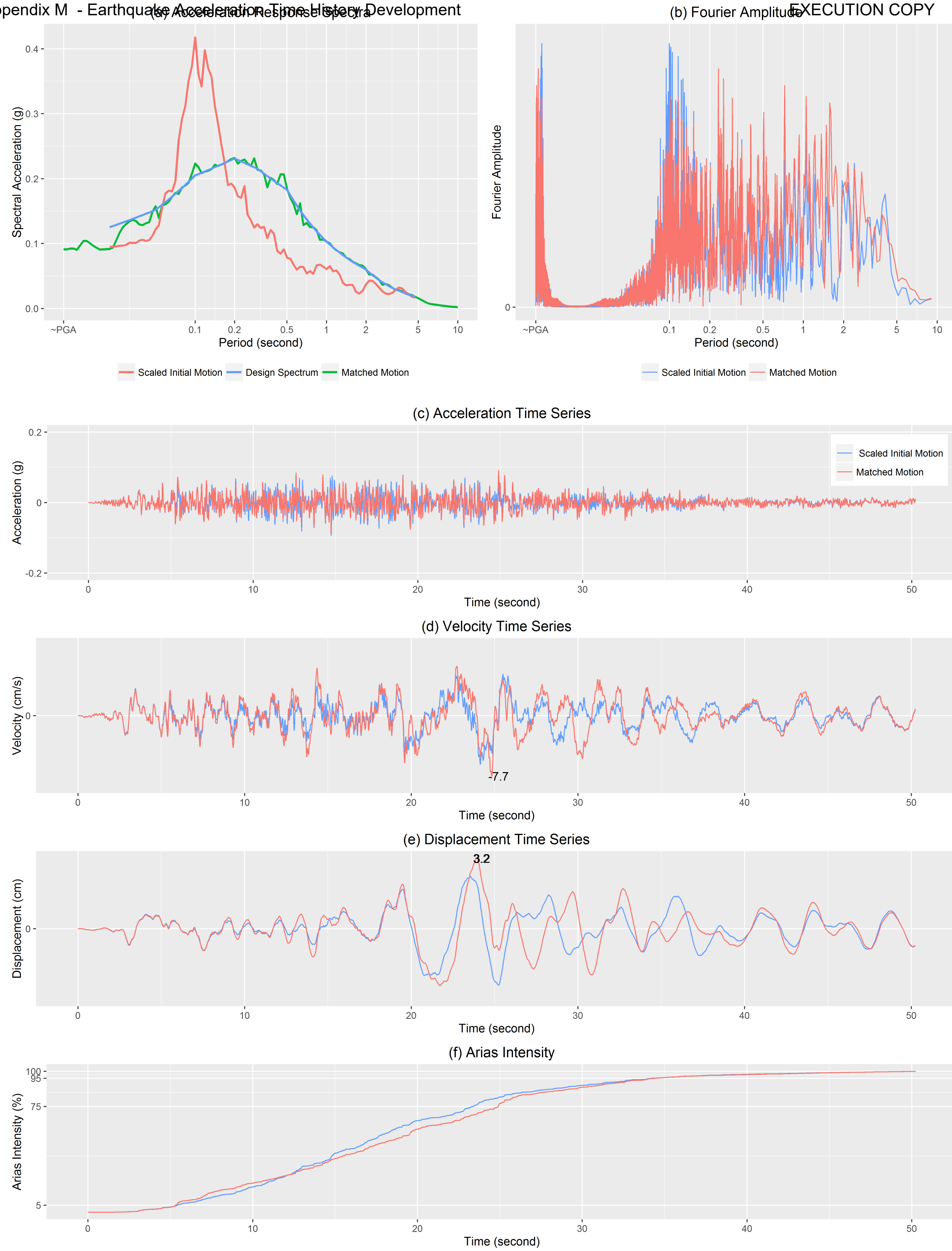
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A61

2018−11−27 16:35:52 FLI



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

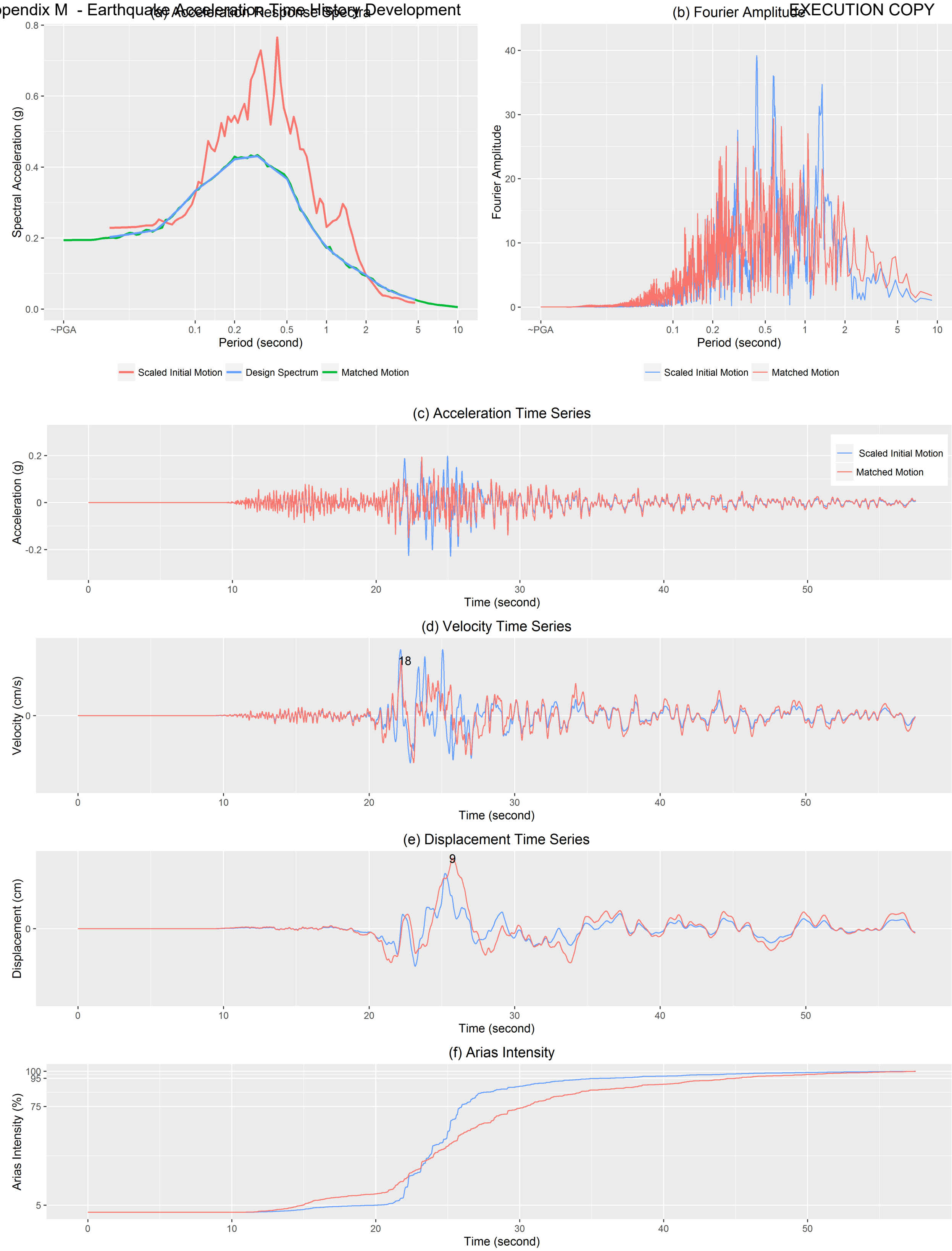
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A62

2018−11−27 16:36:00 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

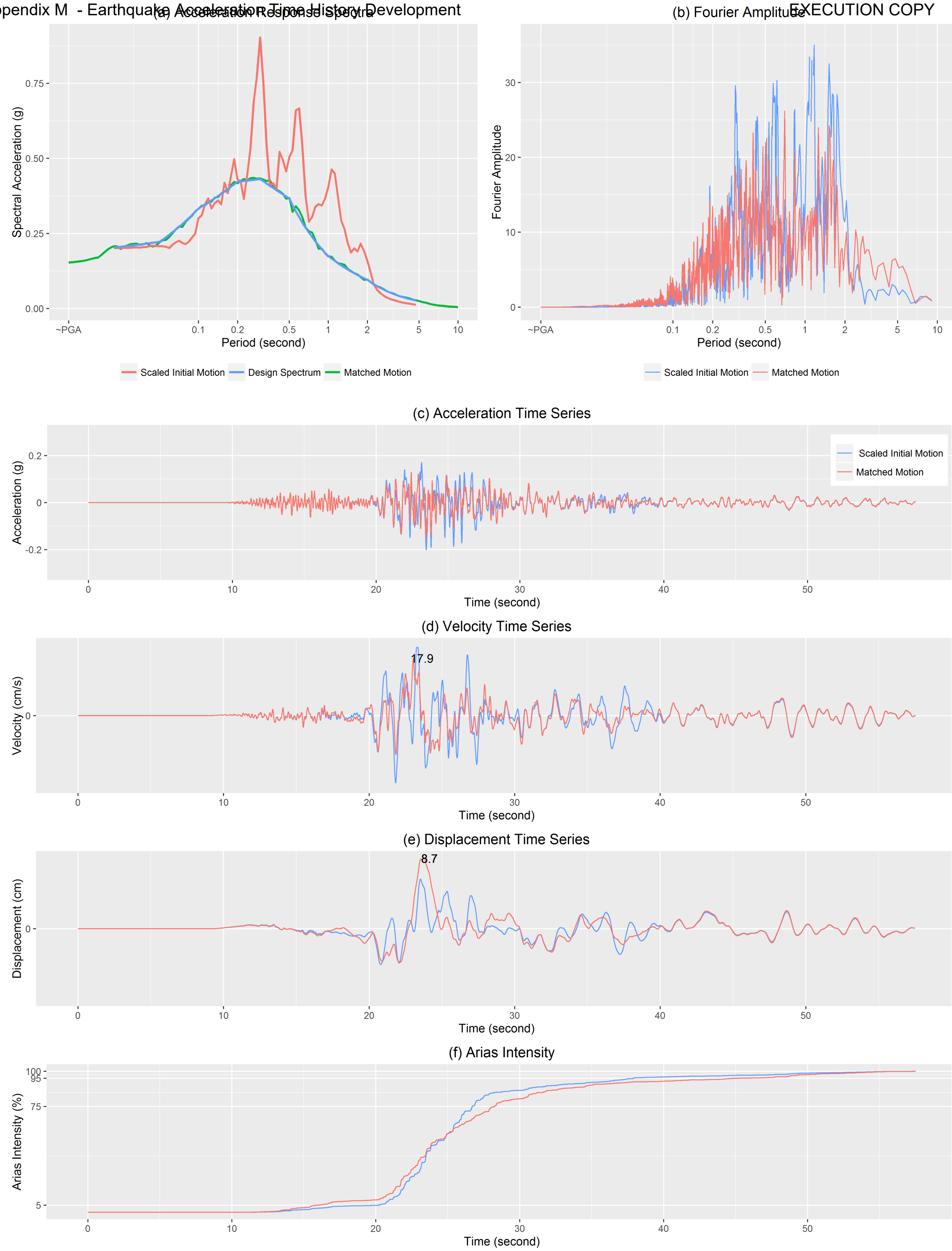
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 125)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A63

2018-11-27 16:36:08 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

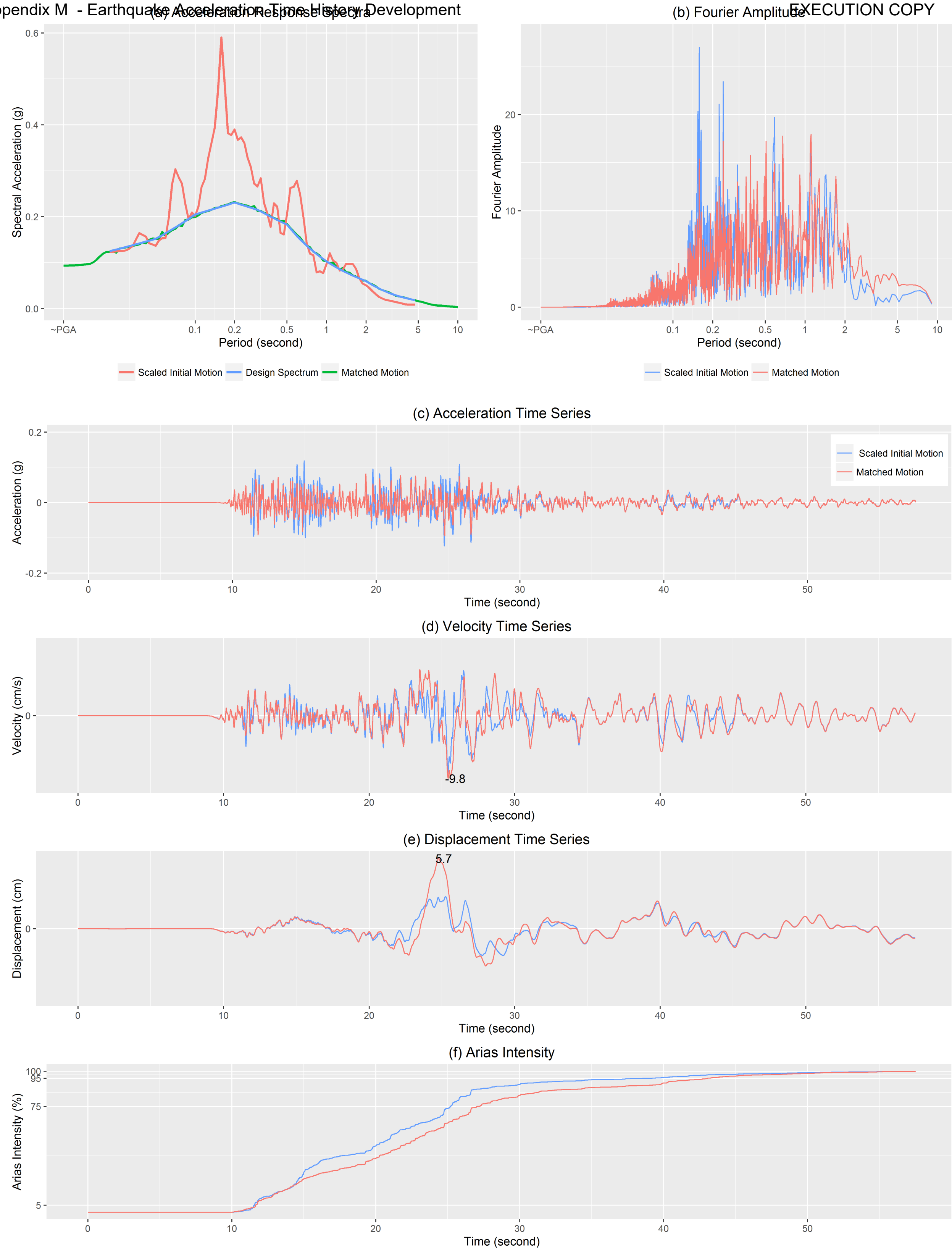
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 215)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A64

2018−11−27 16:36:16 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

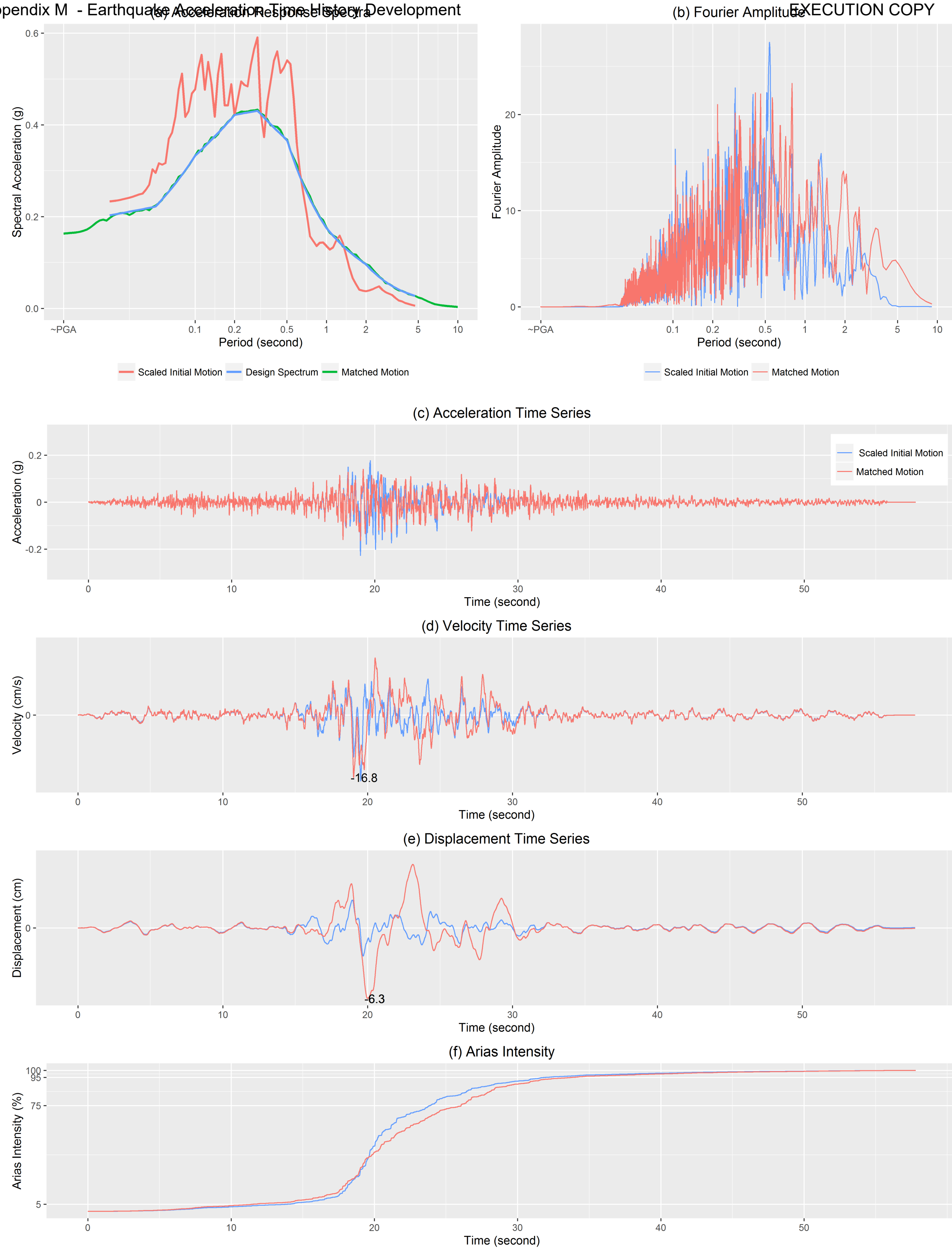
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A65

2018−11−27 16:36:24 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

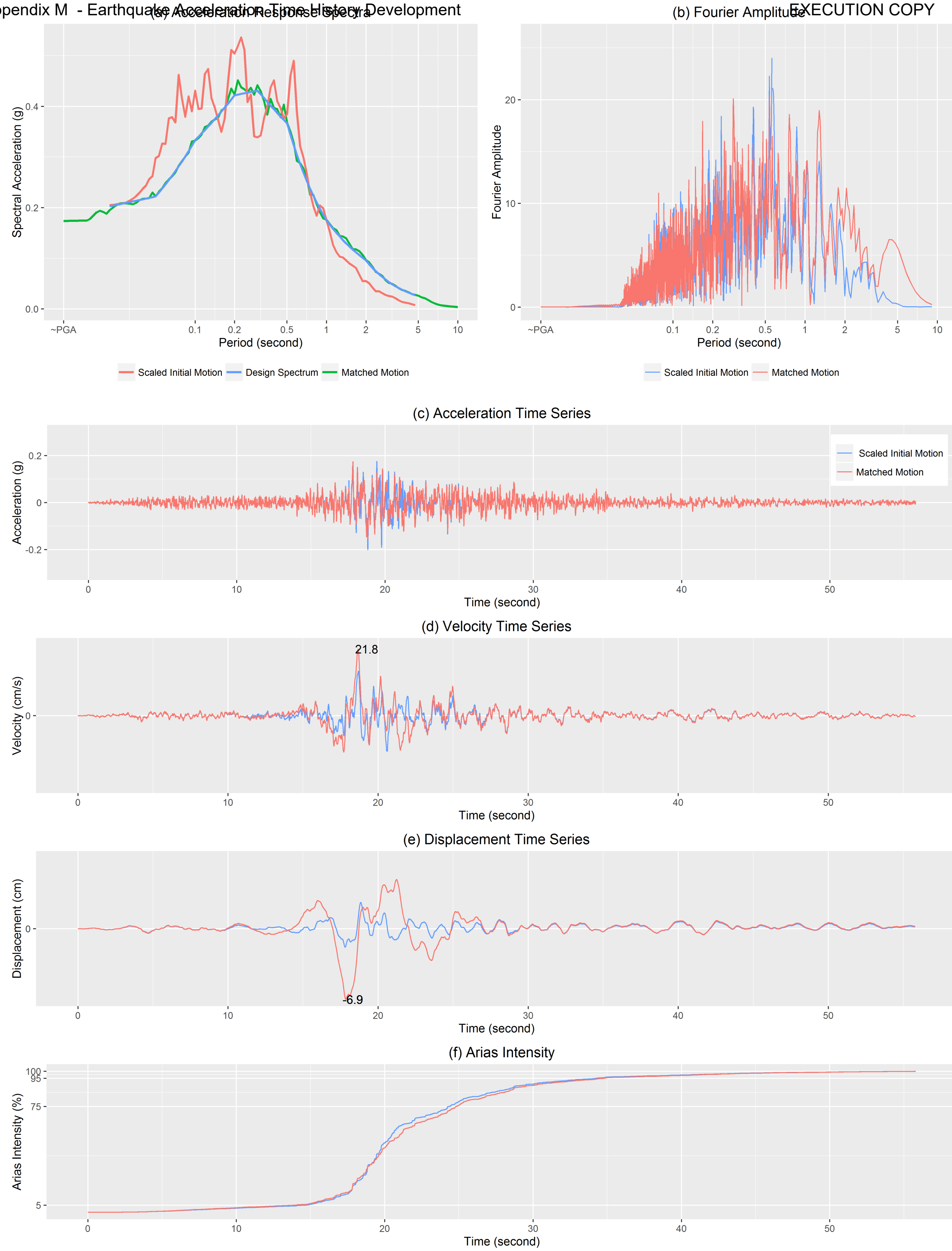
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, L)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A66

2018-11-27 16:36:31 FLi

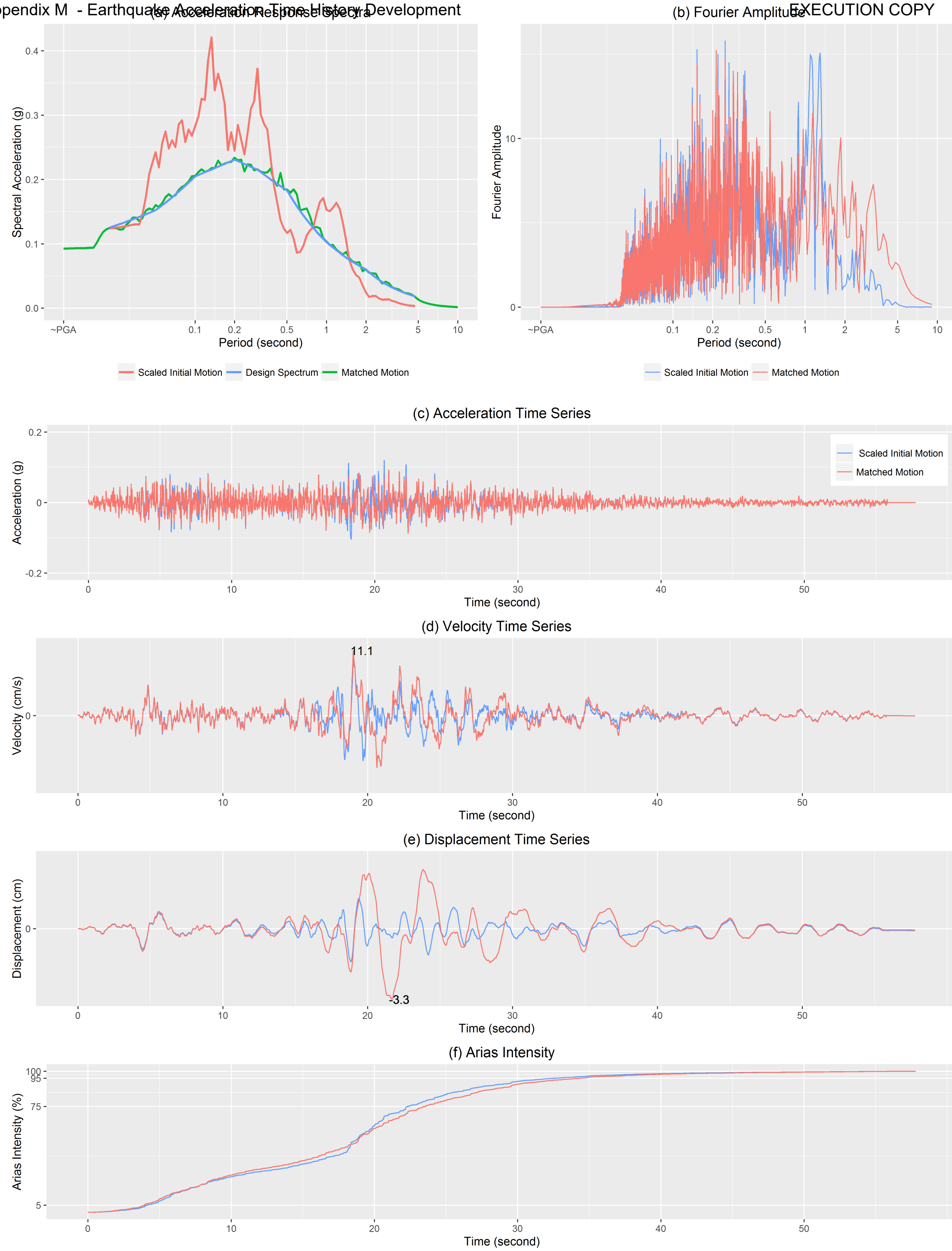


CLIENT		PROJECT	
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**	
CONSULTANT		TITLE	
DD/MM/YYYY	11/27/2018	**SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, T)**	
PREPARED	AR		
DESIGN	AR		
REVIEW	FL		
APPROVED	AH		

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A67

GOLDER

2018−11−27 16:36:39 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

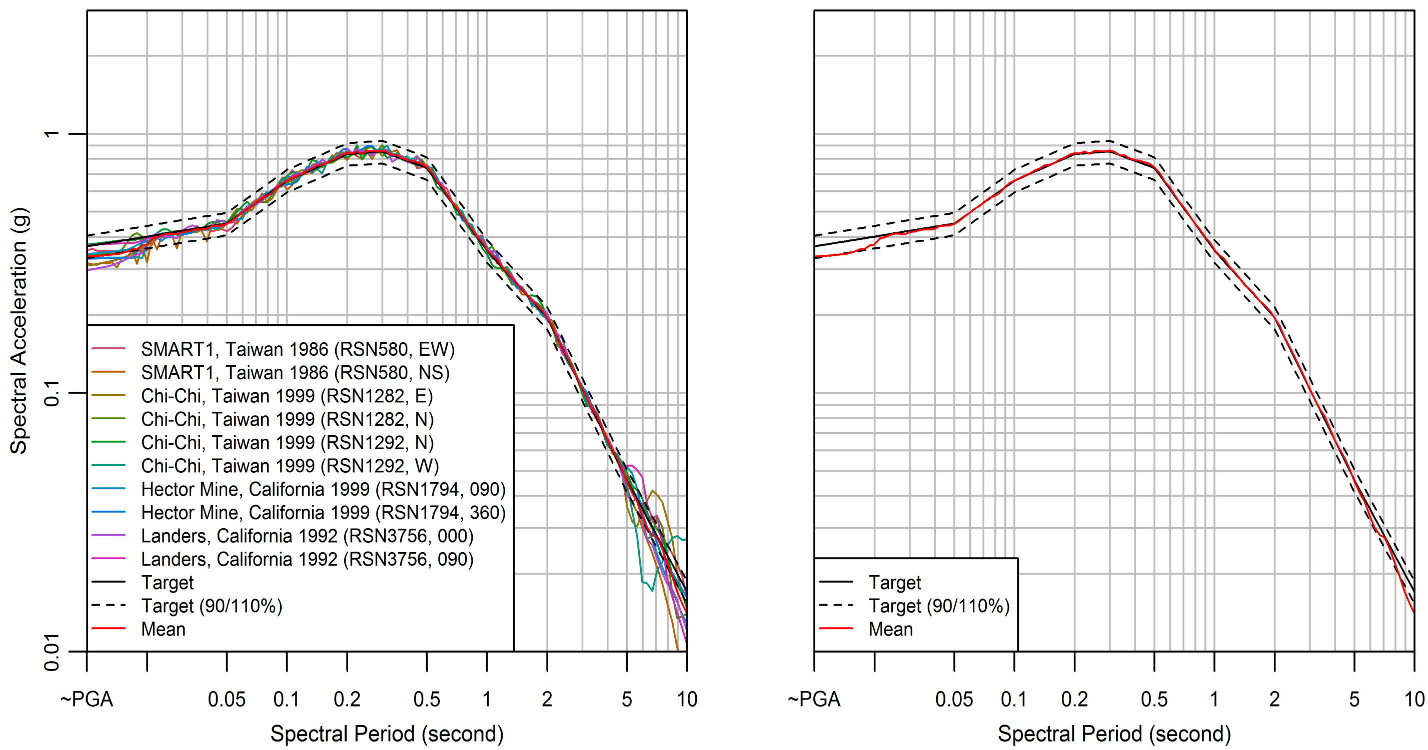
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	DRAFT	A68

2018-11-27 16:36:47 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

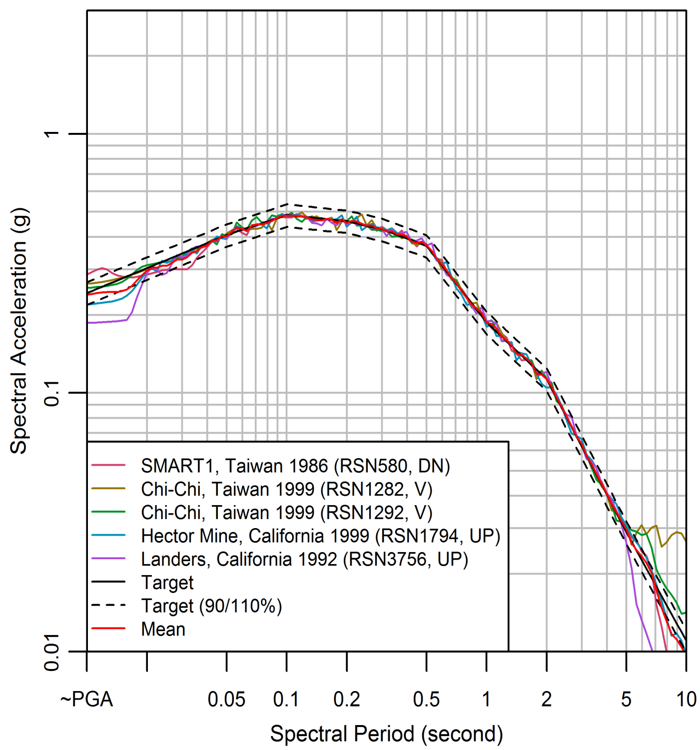
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

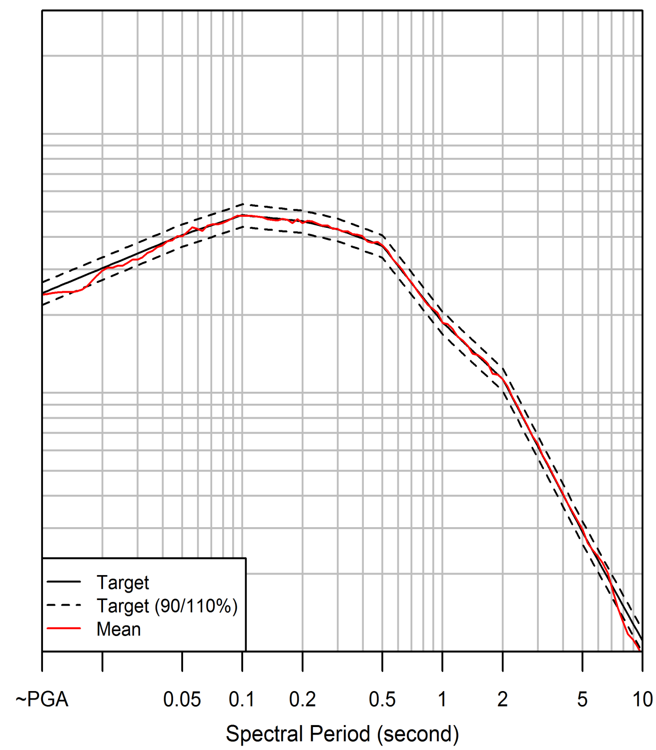
TITLE

COMPARISON OF HORIZONTAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A69

2018-11-27 16:26:17 FLi





CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

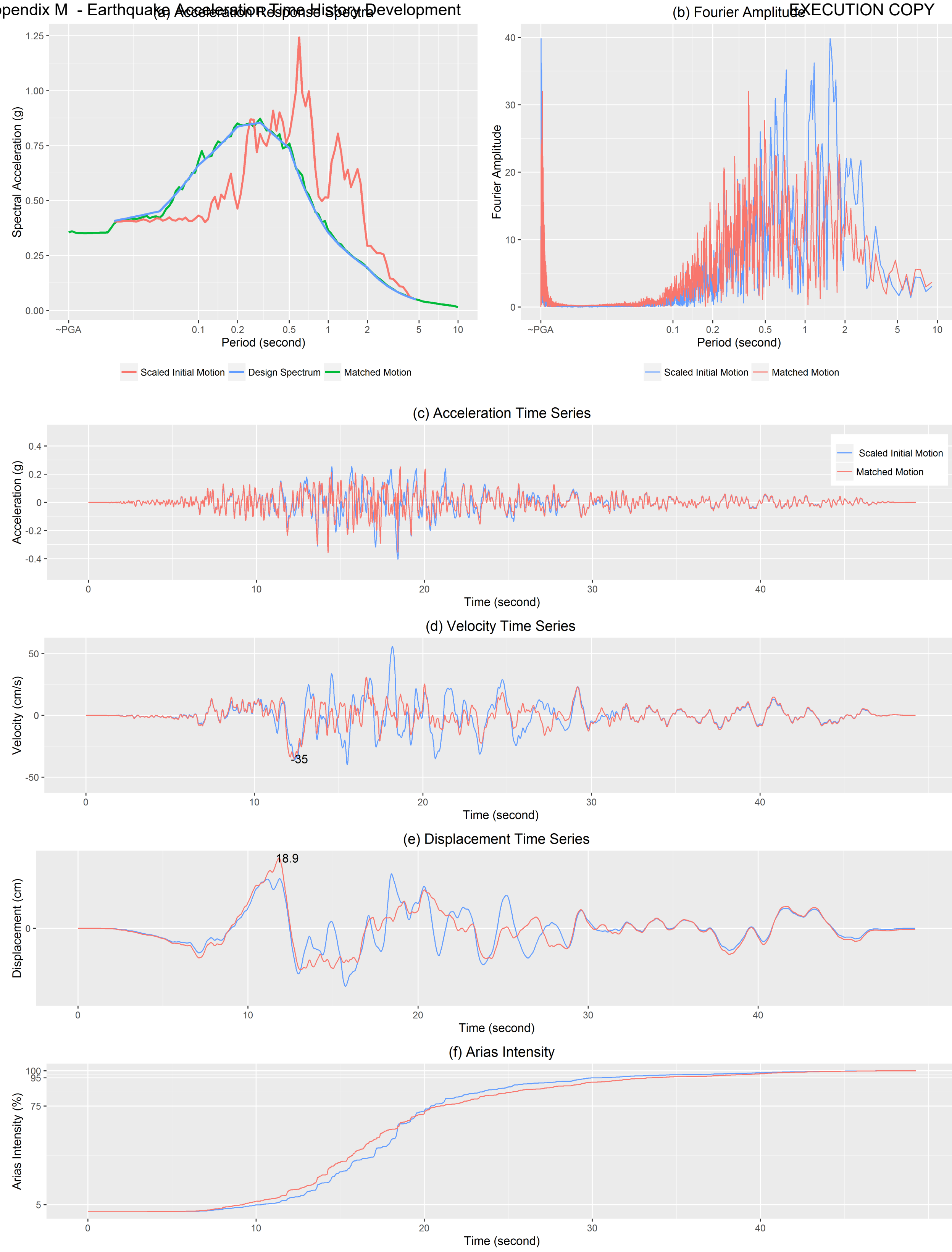
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF VERTICAL CRUSTAL TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A70

2018−11−27 16:26:20 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

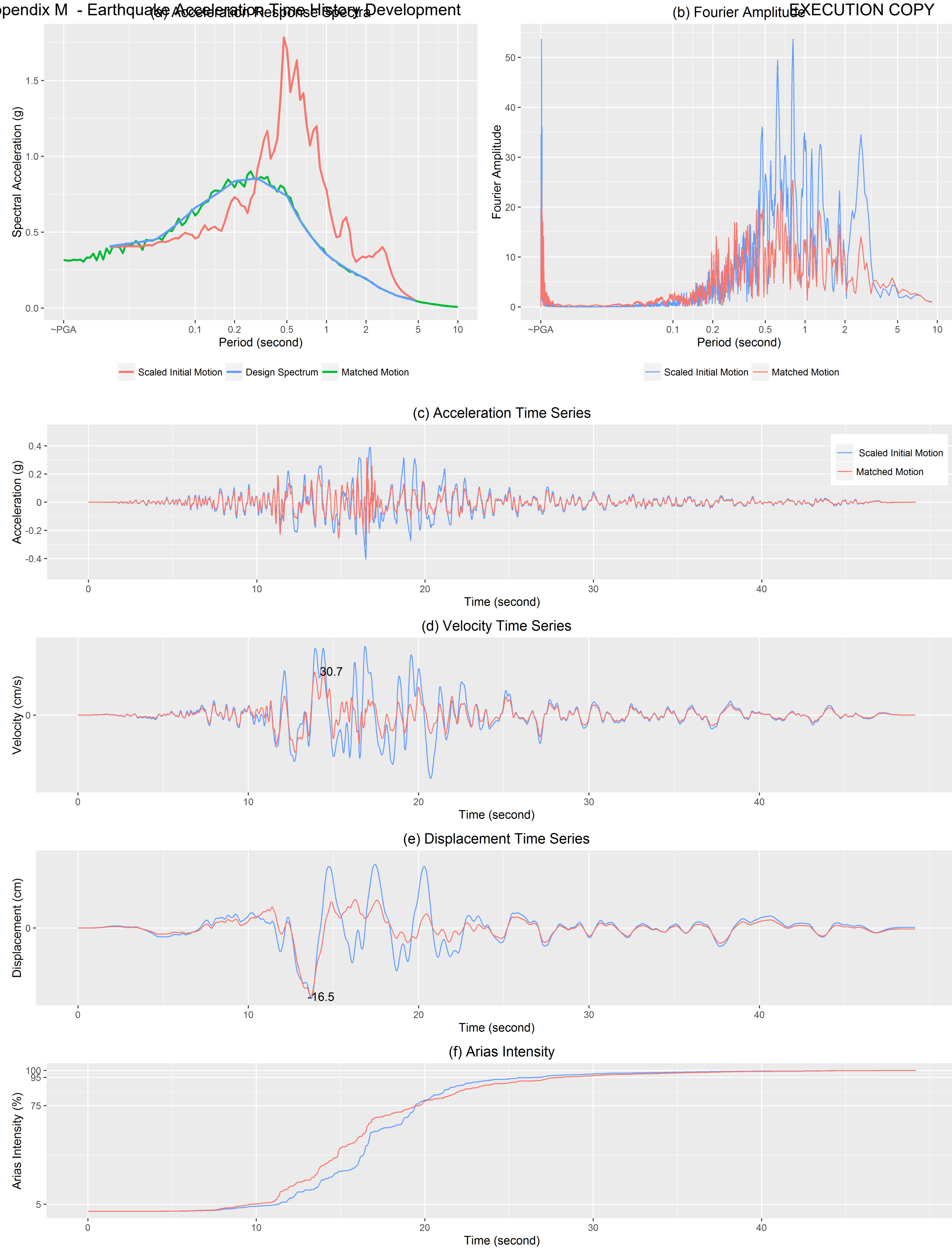
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, EW)

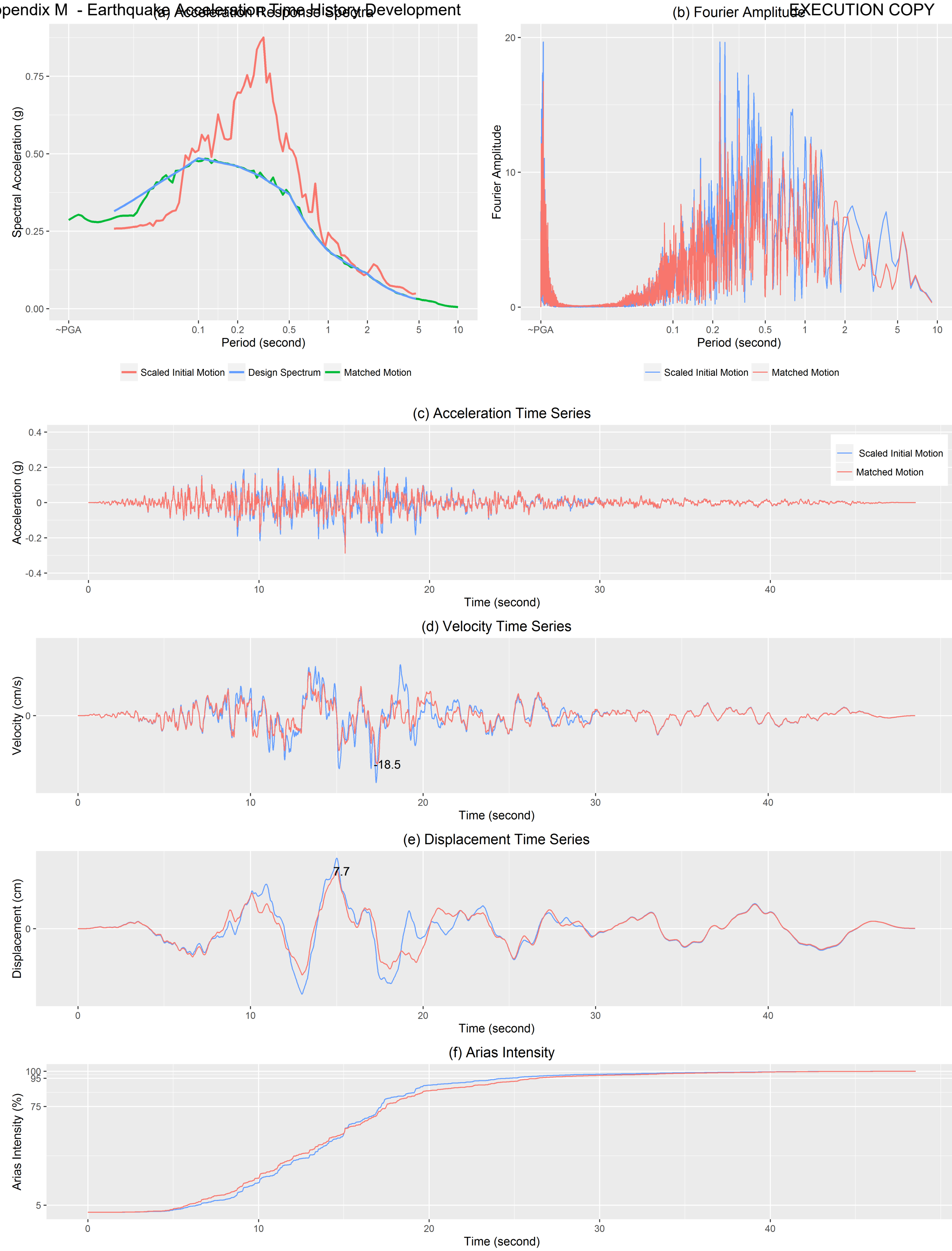
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A71

2018-11-27 16:26:22 FLi



CLIENT **STANTEC CONSULTANTS INC.**		PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**	
CONSULTANT GOLDER	DD/MM/YYYY 11/27/2018 PREPARED AR DESIGN AR REVIEW FL APPROVED AH	TITLE **SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, NS)**	
		PROJECT No. 1419105 PHASE 7100 REV. A	FIGURE A72

2018−11−27 16:26:30 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

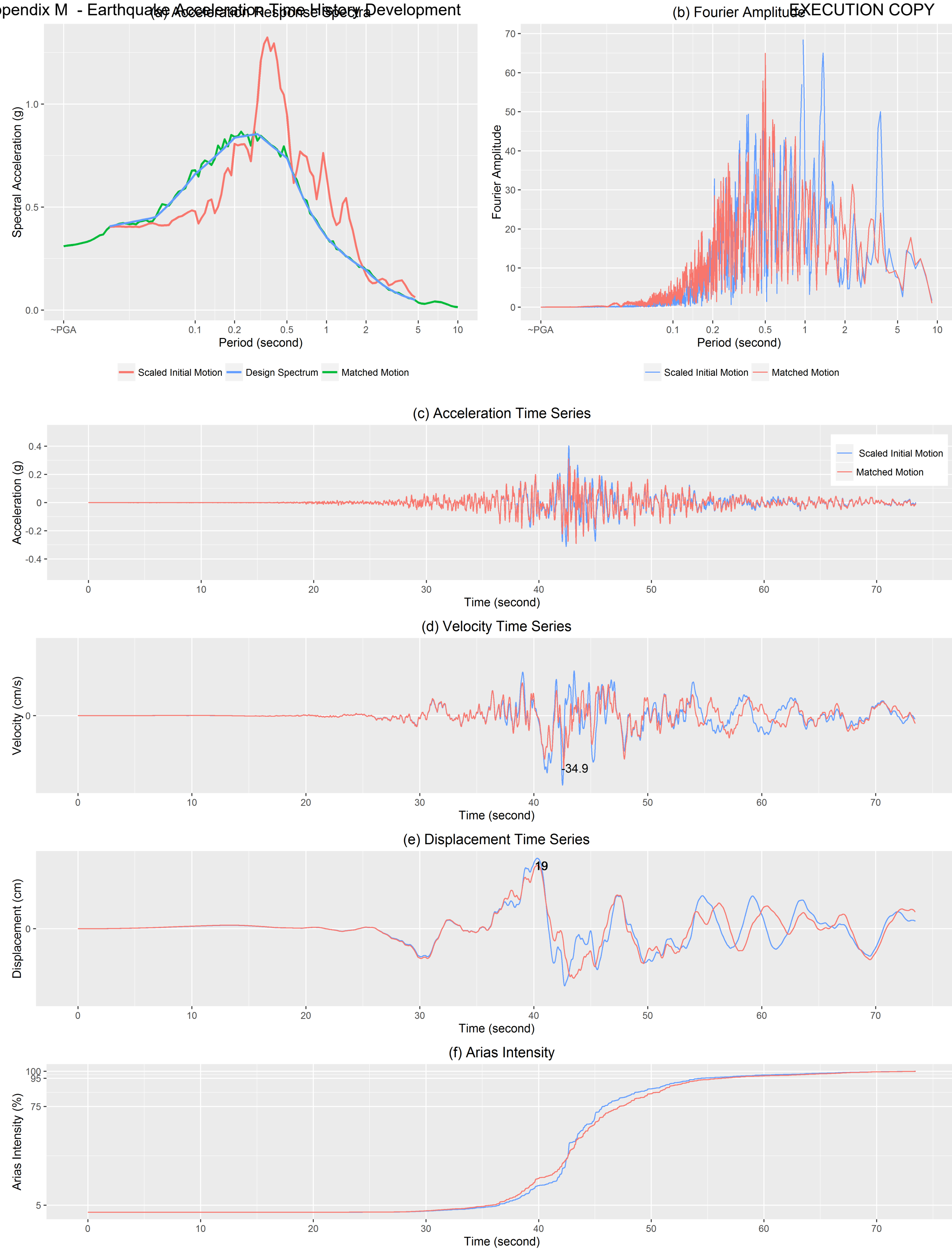
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TAIWAN SMART1 (1986, SMART1 006, DN)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A73



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

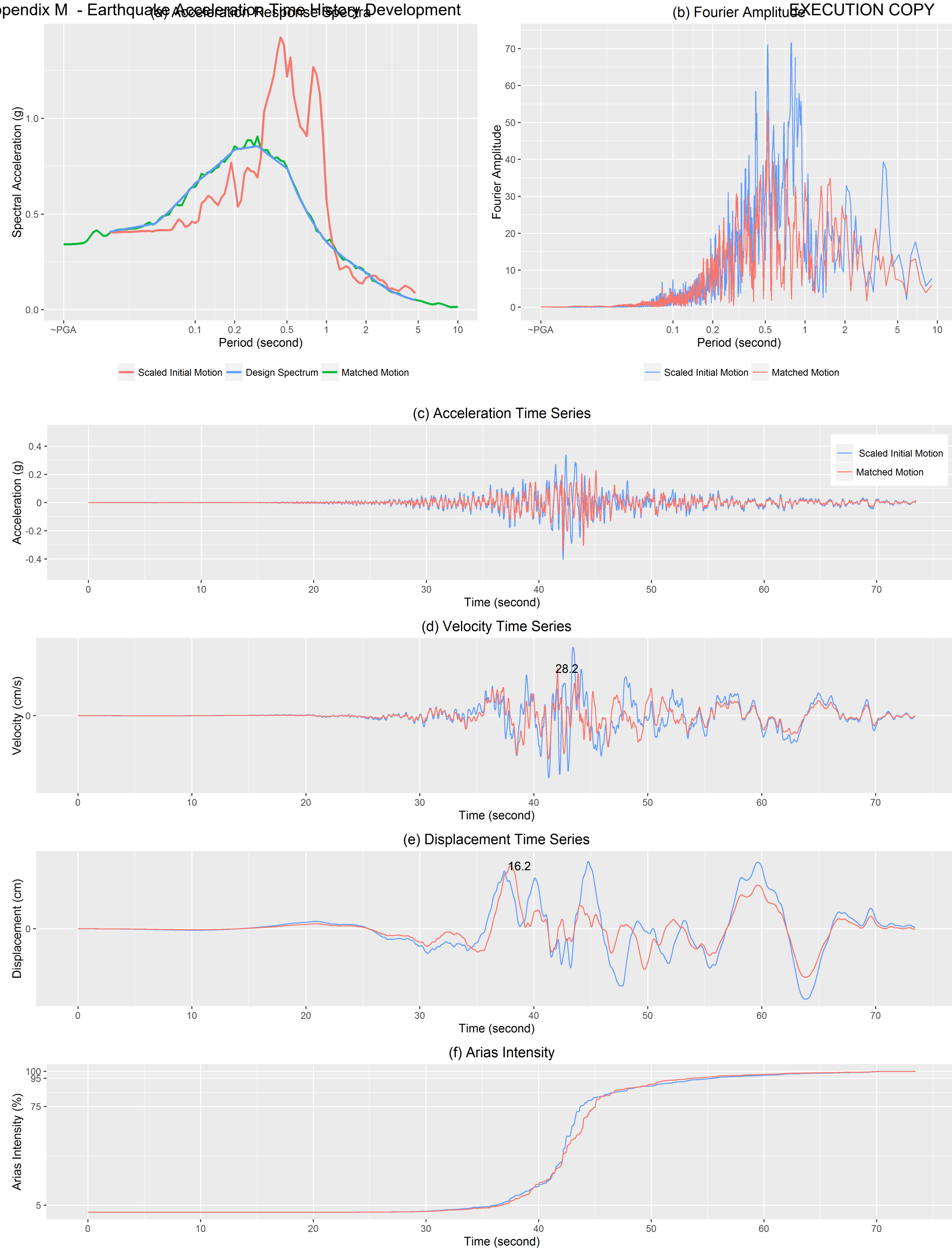
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A74

2018-11-27 16:26:46 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

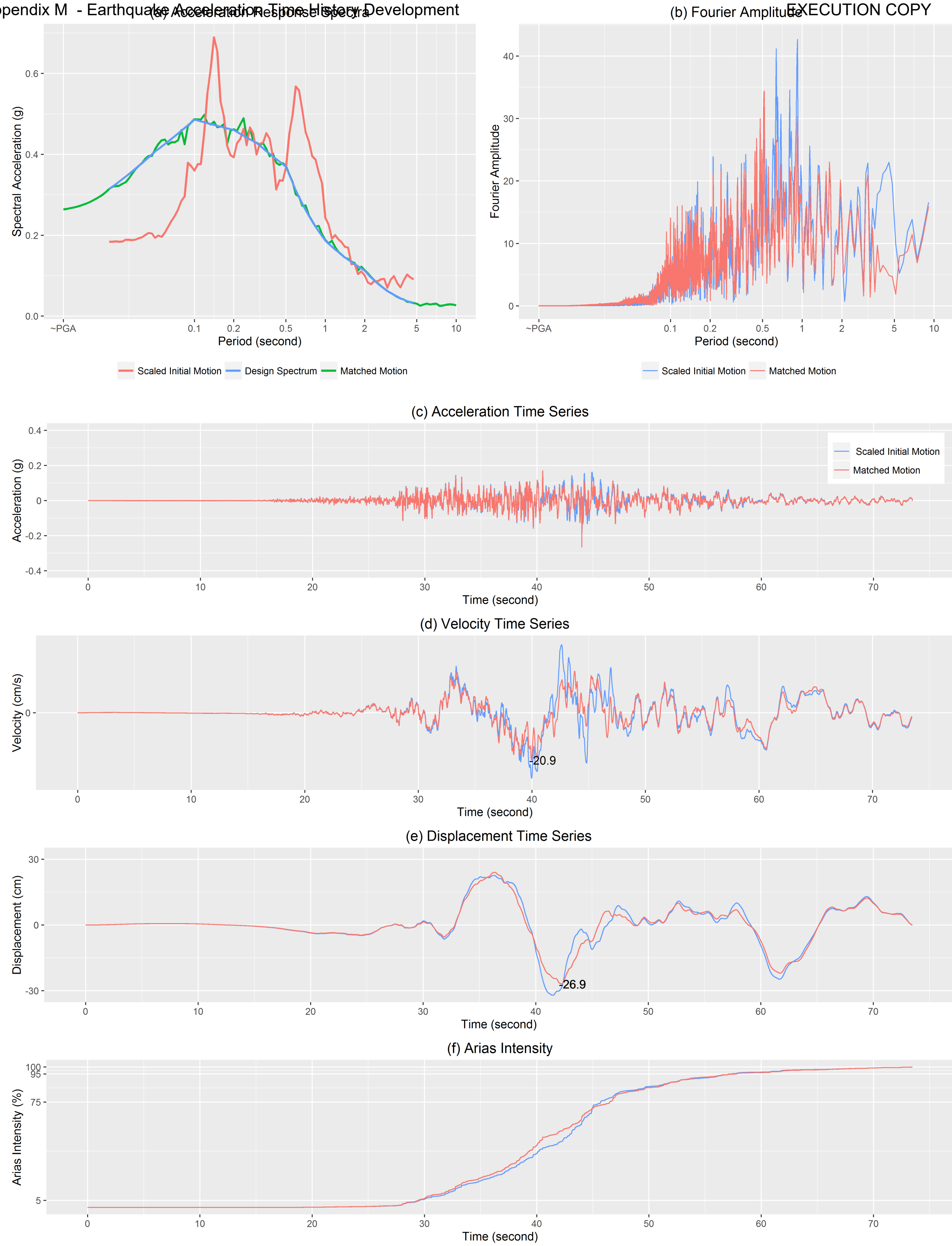
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A75

2018−11−27 16:26:54 FLi



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STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

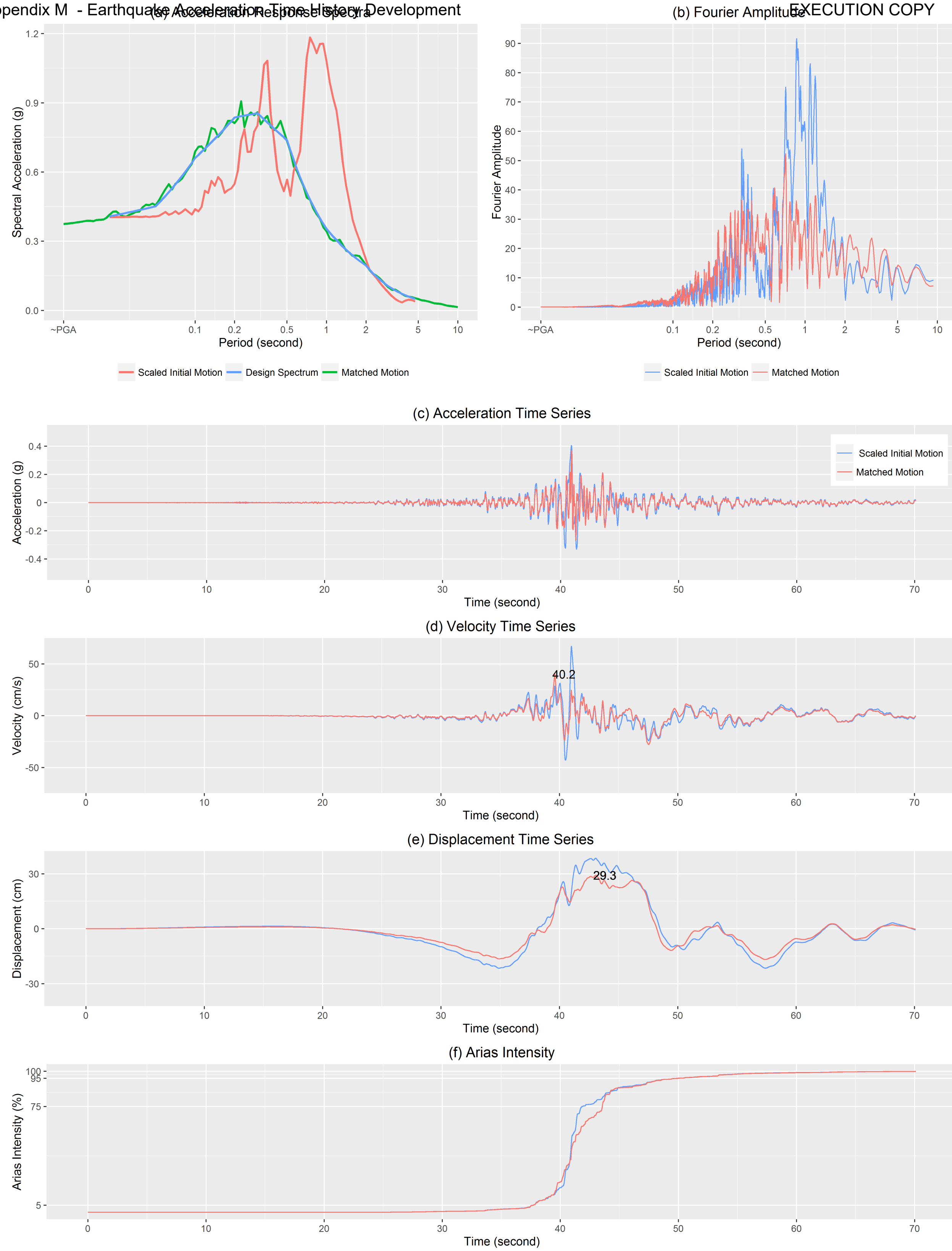
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA033, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A76



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

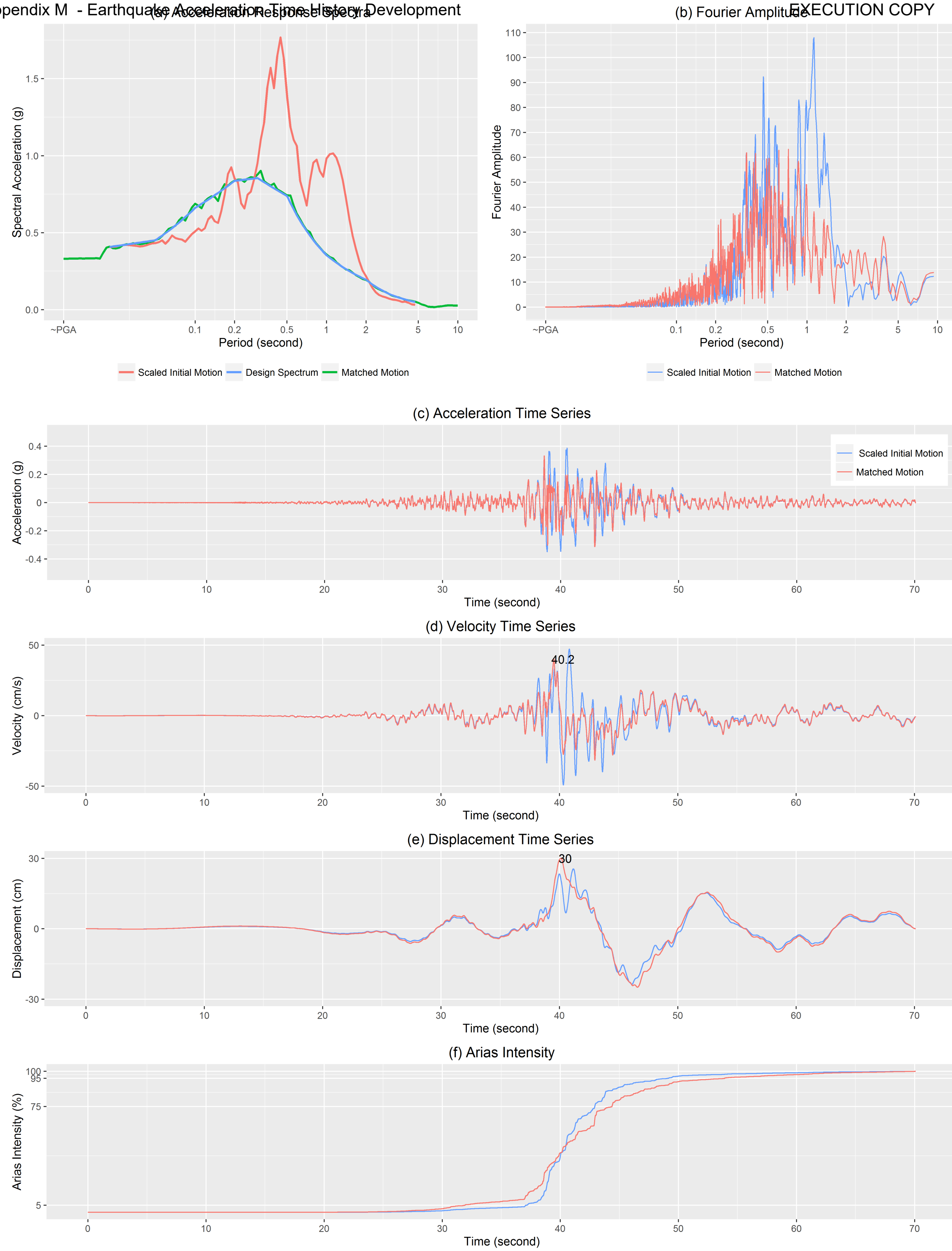
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A77

2018-11-27 16:27:10 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

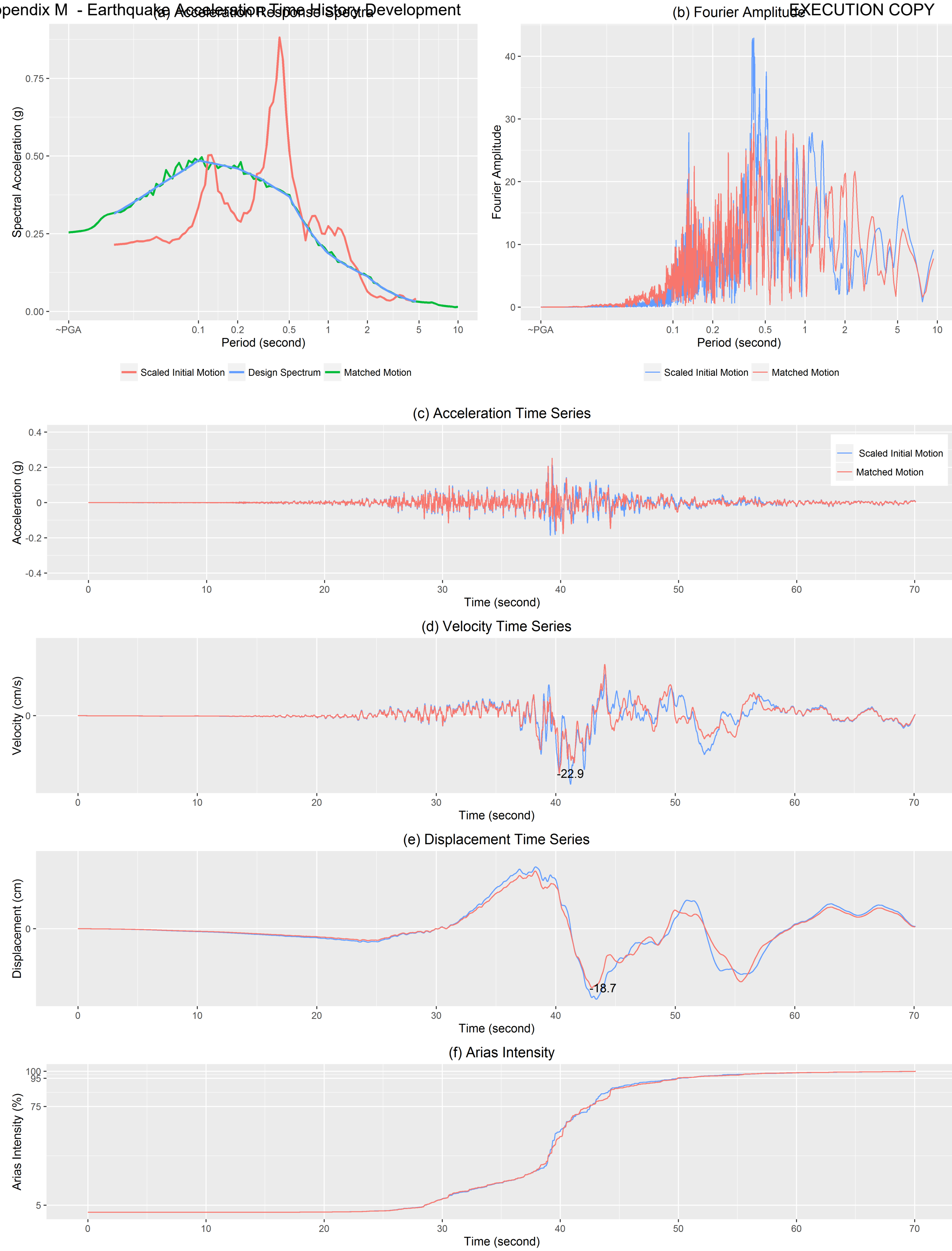
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, W)

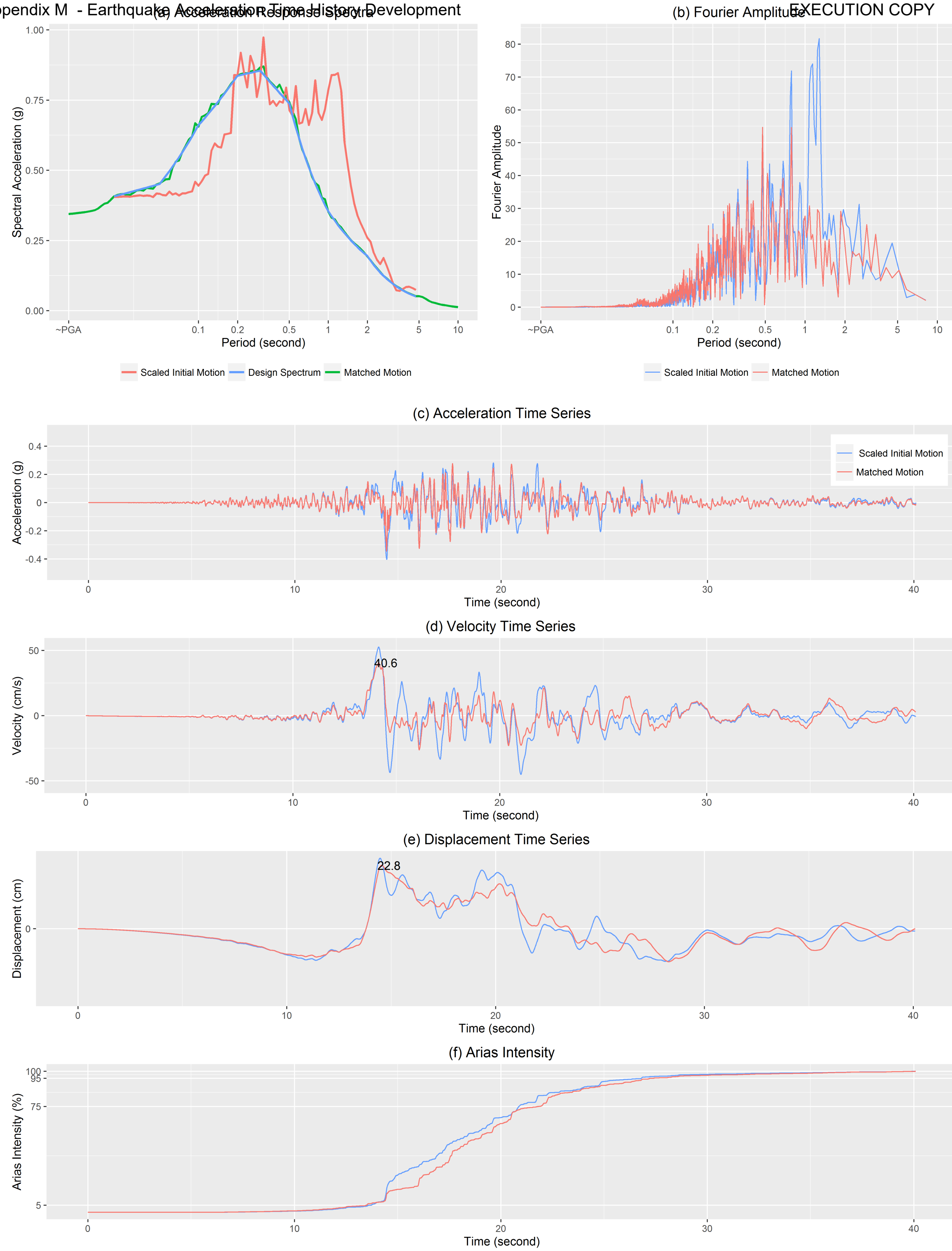
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A78

2018−11−27 16:27:18 FLi



CLIENT		PROJECT
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**
CONSULTANT	DD/MM/YYYY 11/27/2018	TITLE
GOLDER	PREPARED AR	**SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD CHI−CHI, TAIWAN (1999, HWA045, V)**
	DESIGN AR	
	REVIEW FL	PROJECT No. 1419105 / PHASE 7100 / REV. A / FIGURE A79
	APPROVED AH	

2018-11-27 16:27:26 FLi



CLIENT		PROJECT
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

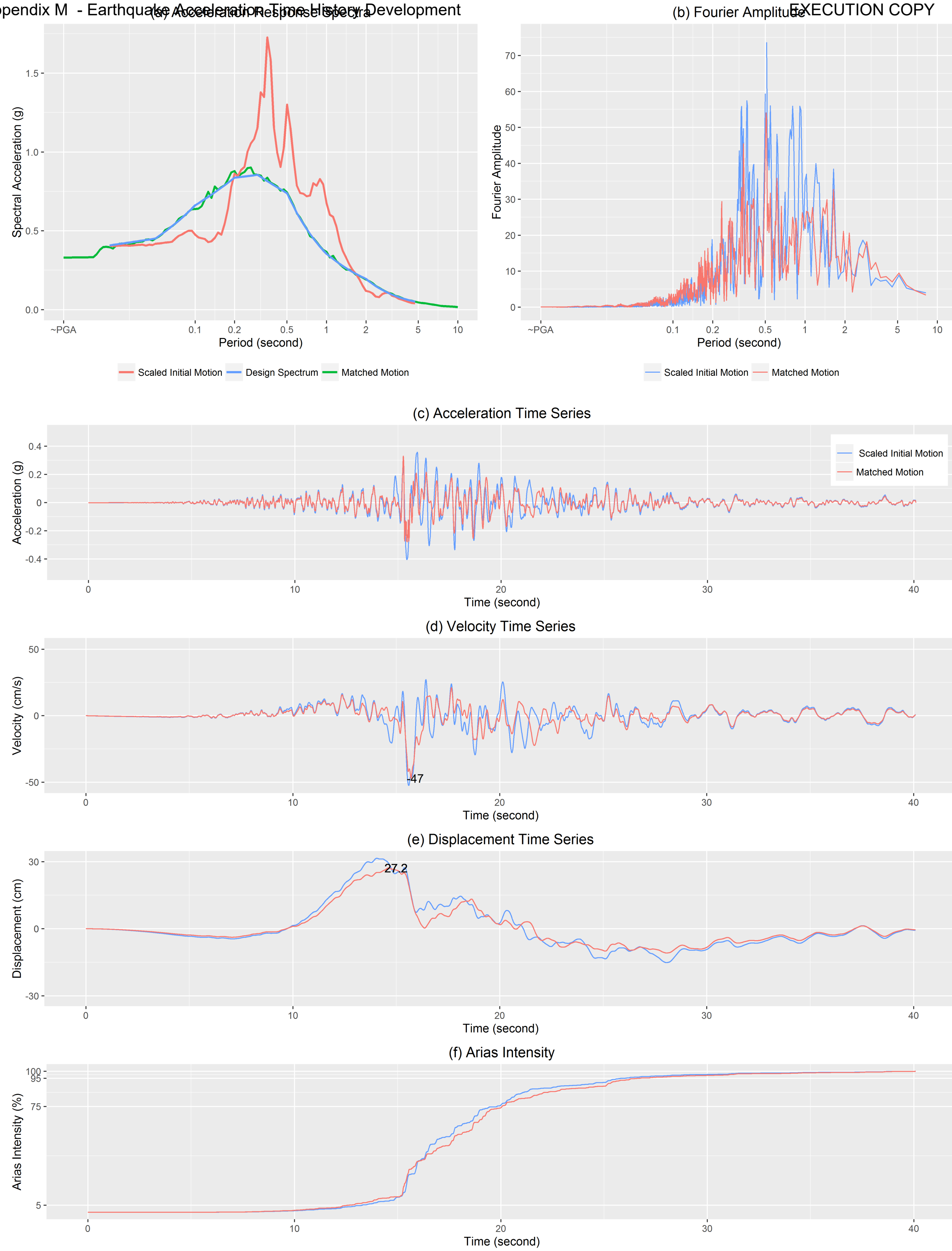
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A80

2018-11-27 16:27:34 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

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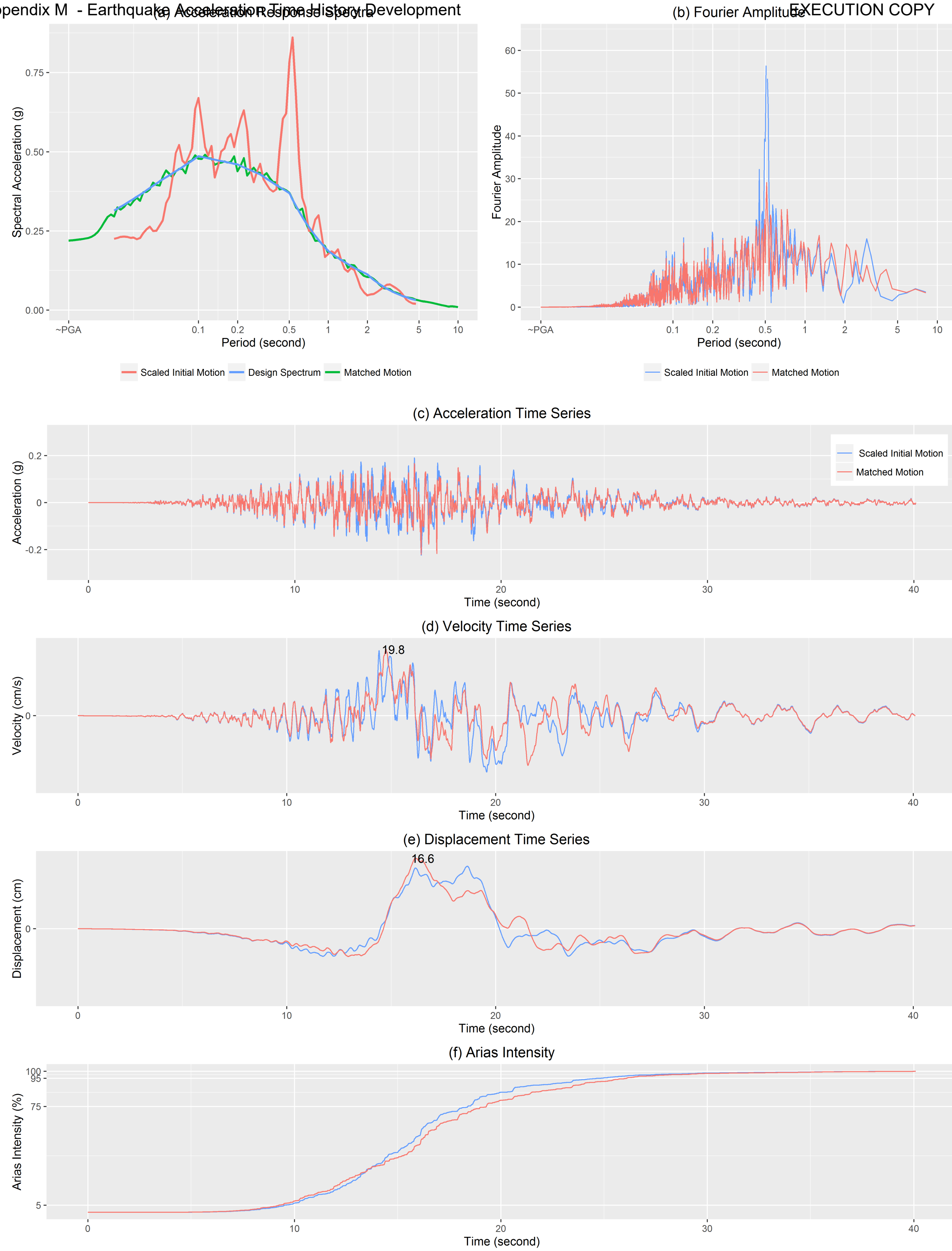
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, 360)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A81

2018-11-27 16:27:43 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

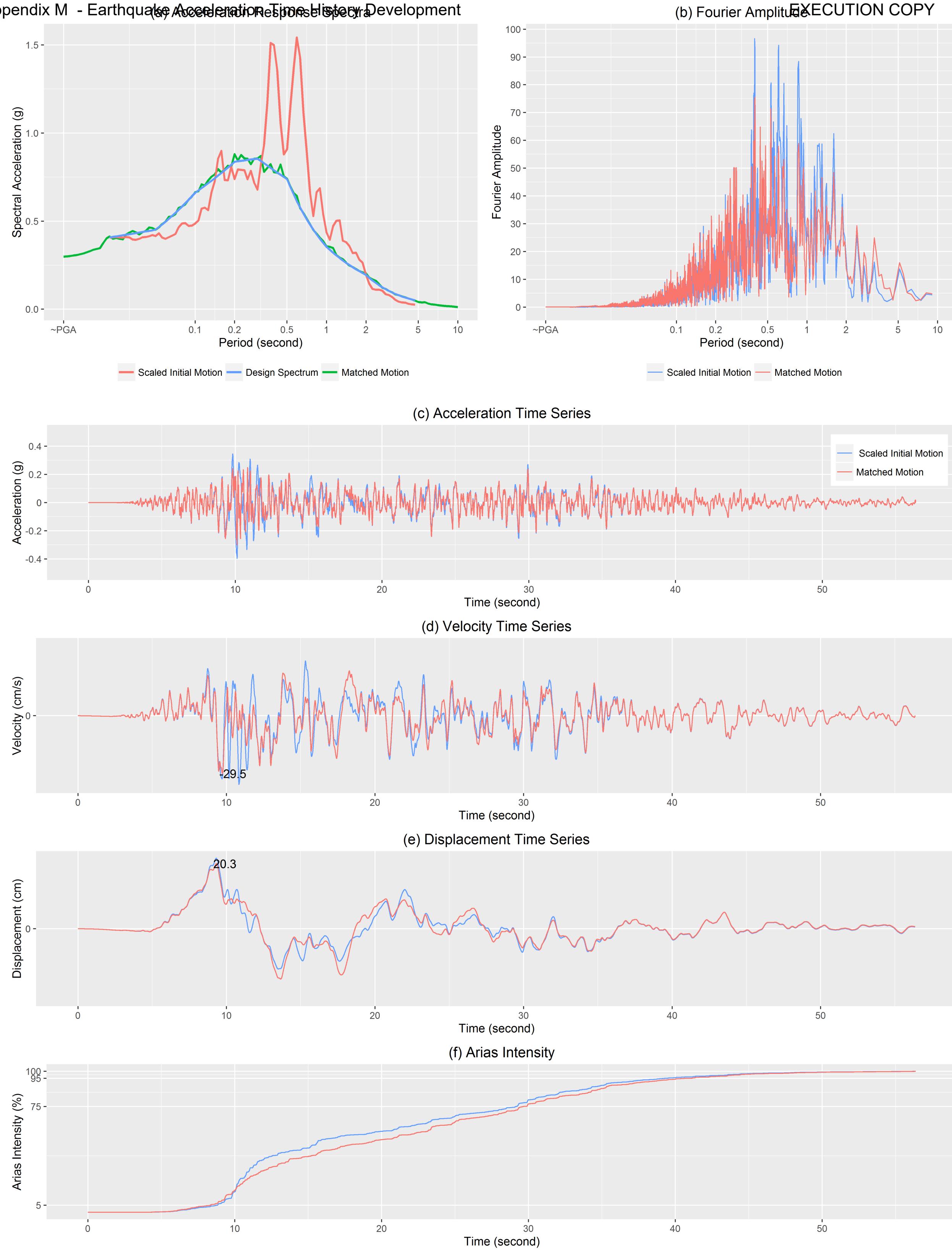
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD HECTOR MINE (1999, JOSHUA TREE, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A82

2018-11-27 16:27:51 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

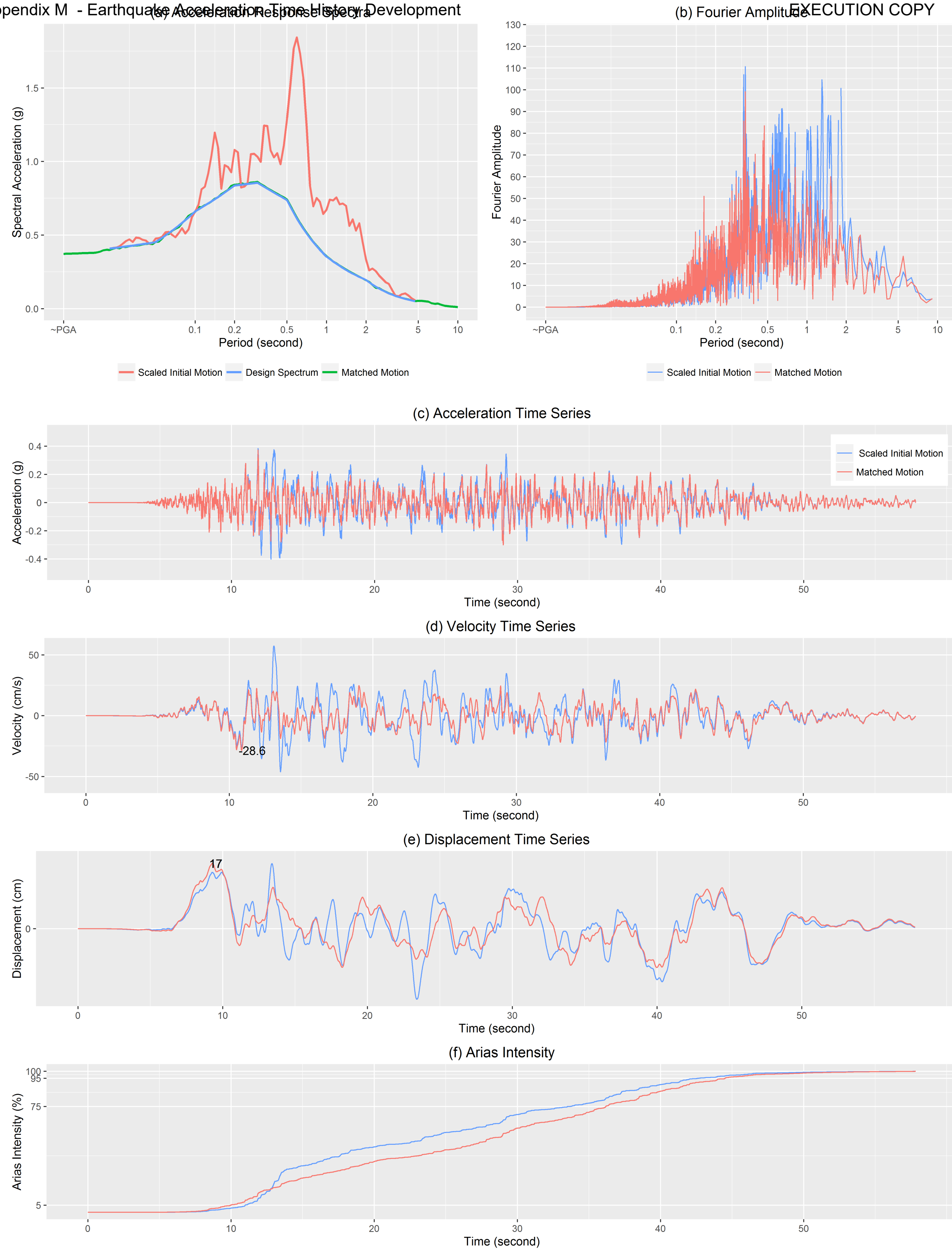
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 0)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A83

2018-11-27 16:27:59 FLI



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

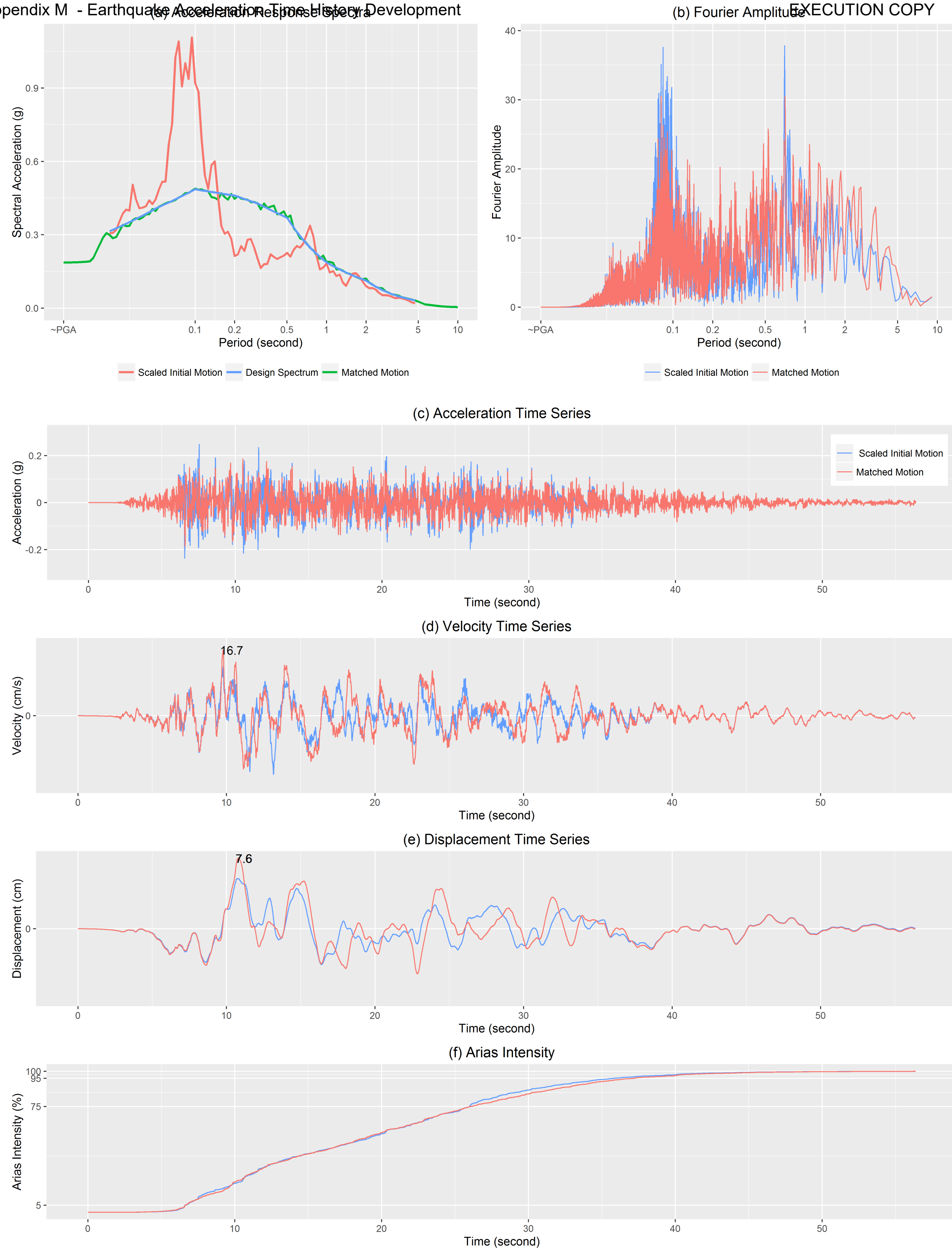
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A84

2018-11-27 16:28:07 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

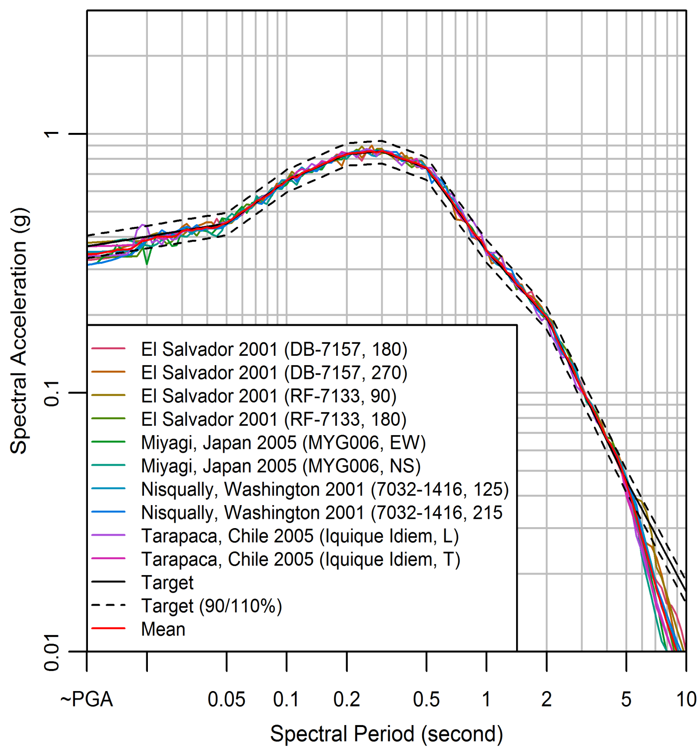
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

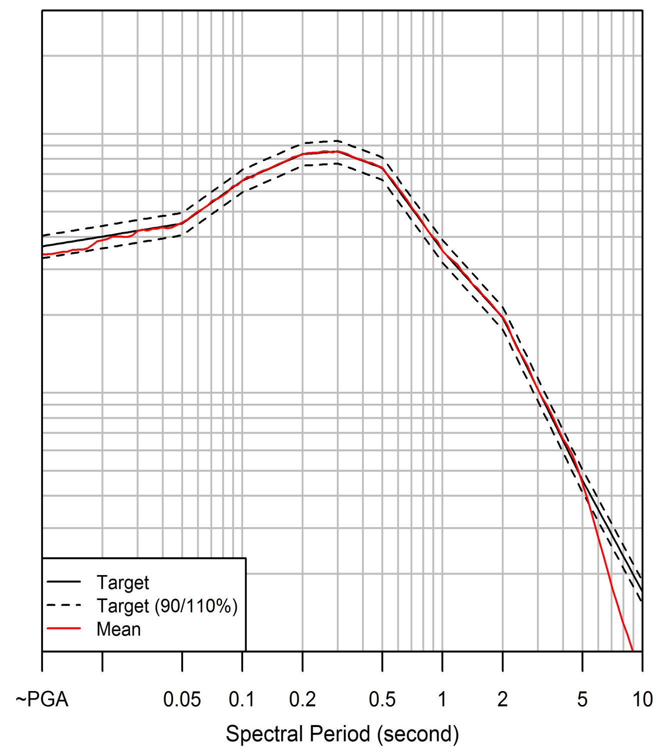
TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD LANDERS (1992, MORONGO VALLEY HALL (GEOS #58), UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A85

2018-11-27 16:28:15 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

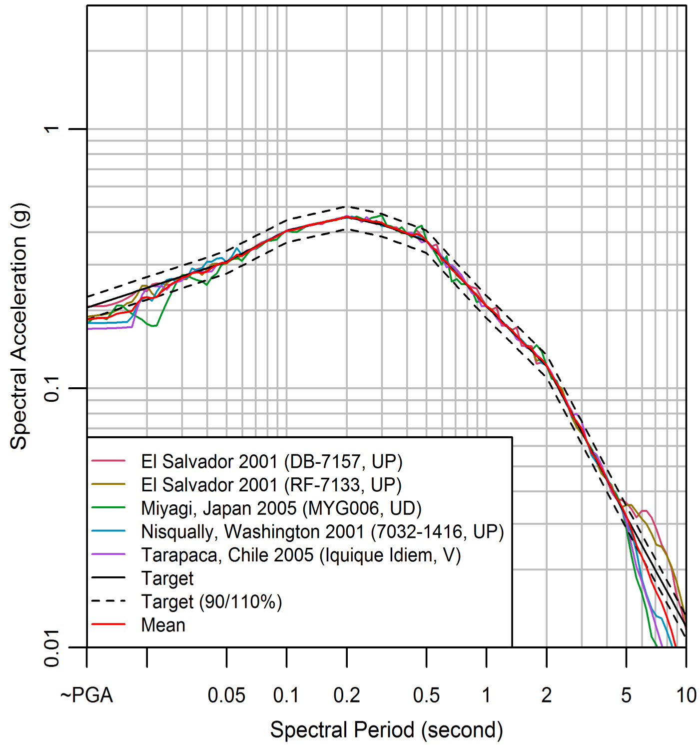
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

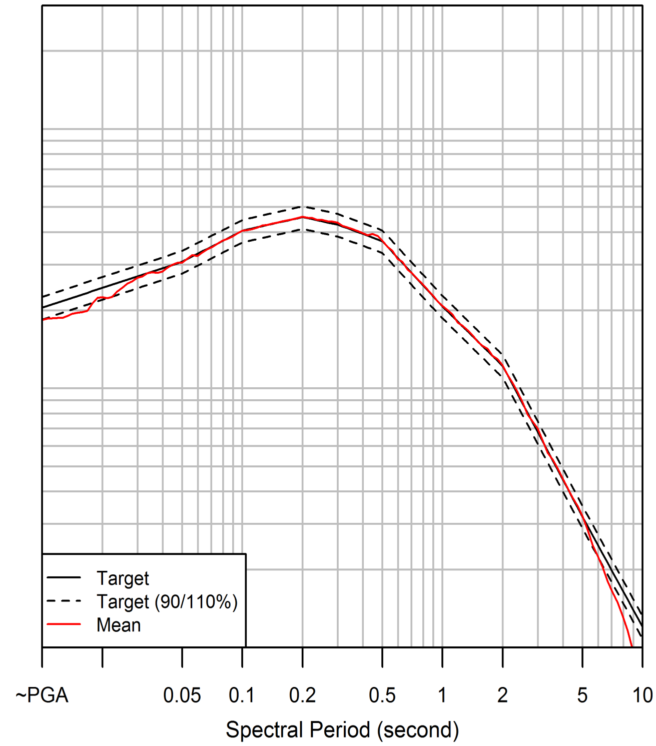
TITLE

COMPARISON OF HORIZONTAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A86

2018-11-27 16:28:23 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

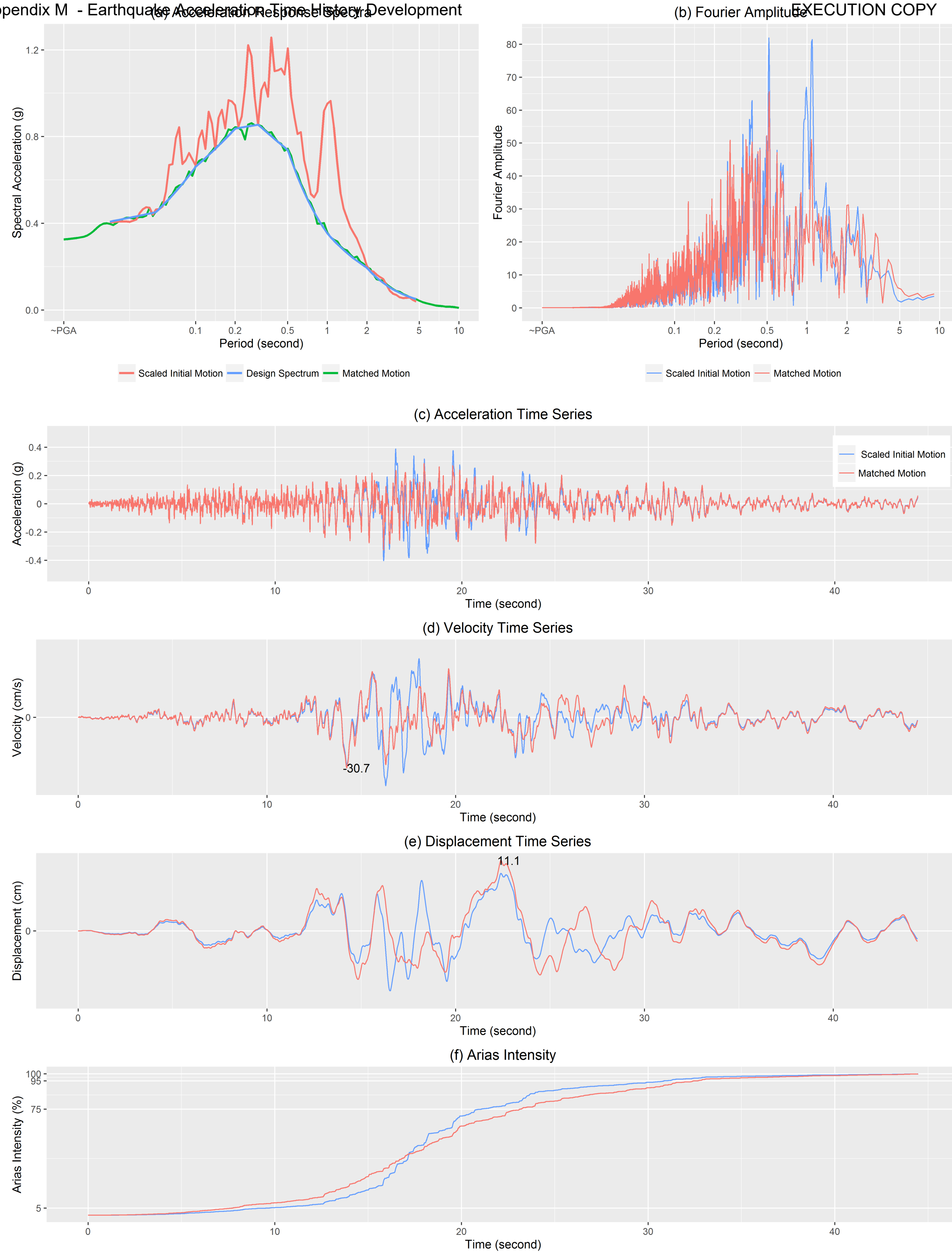
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF VERTICAL INTRASLAB TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A87

2018-11-27 16:28:26 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

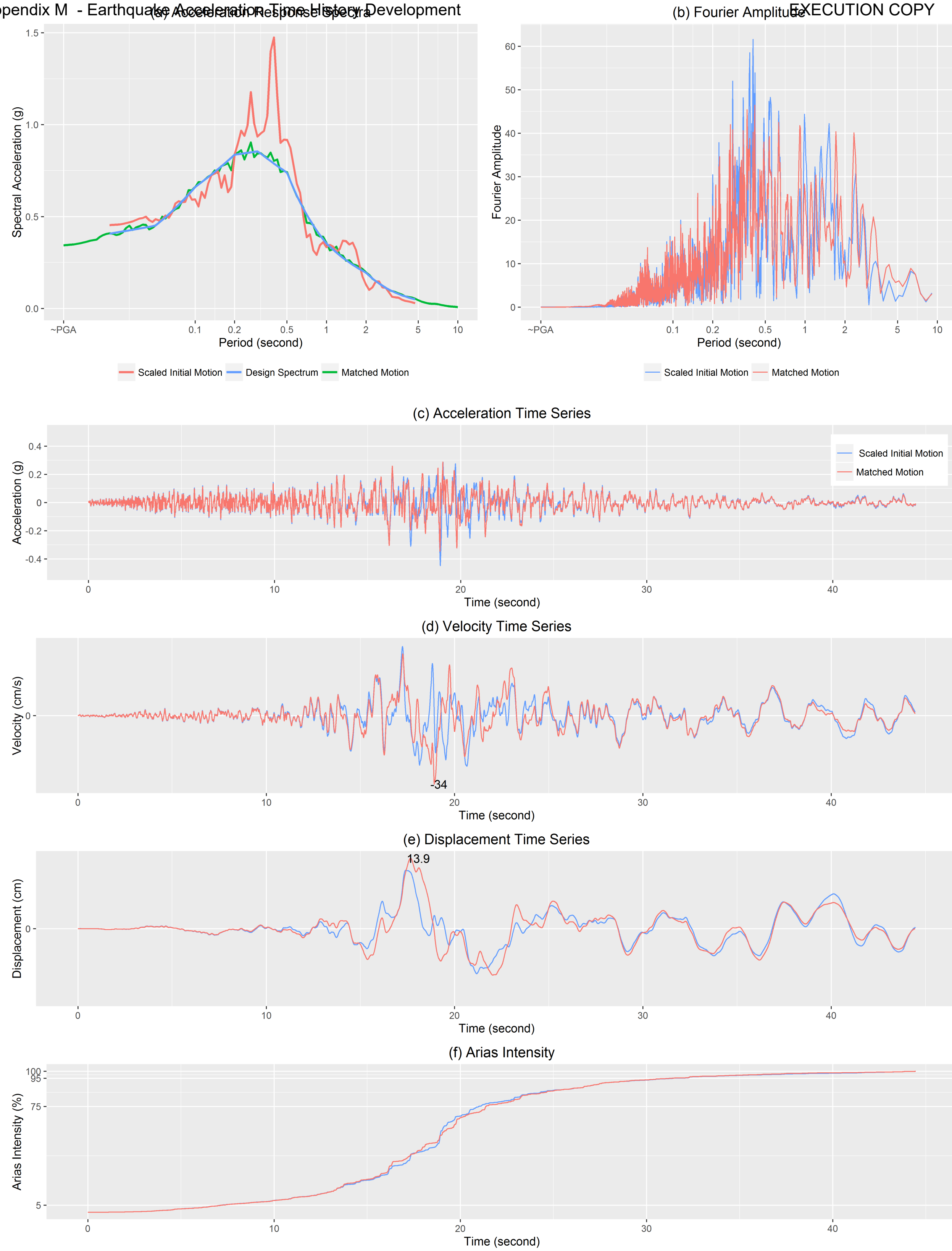
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 180)

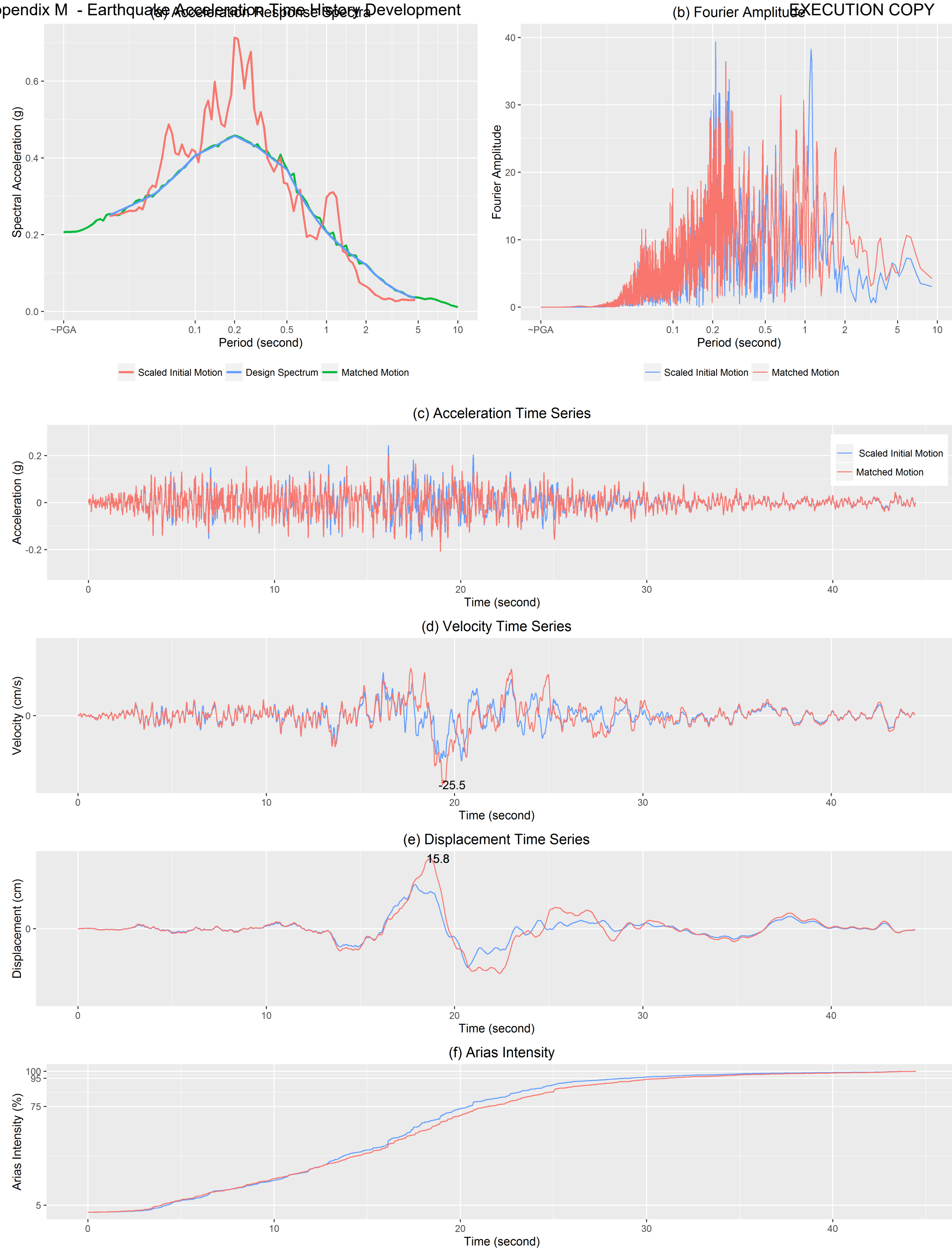
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A88

2018-11-27 16:28:29 FLi



CLIENT **STANTEC CONSULTANTS INC.**		PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**	
CONSULTANT	DD/MM/YYYY 11/27/2018	TITLE **SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, 270)**	
GOLDER	PREPARED AR		
	DESIGN AR		
	REVIEW FL	PROJECT No. 1419105	PHASE 7100
	APPROVED AH	REV. A	FIGURE A89

2018-11-27 16:28:37 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

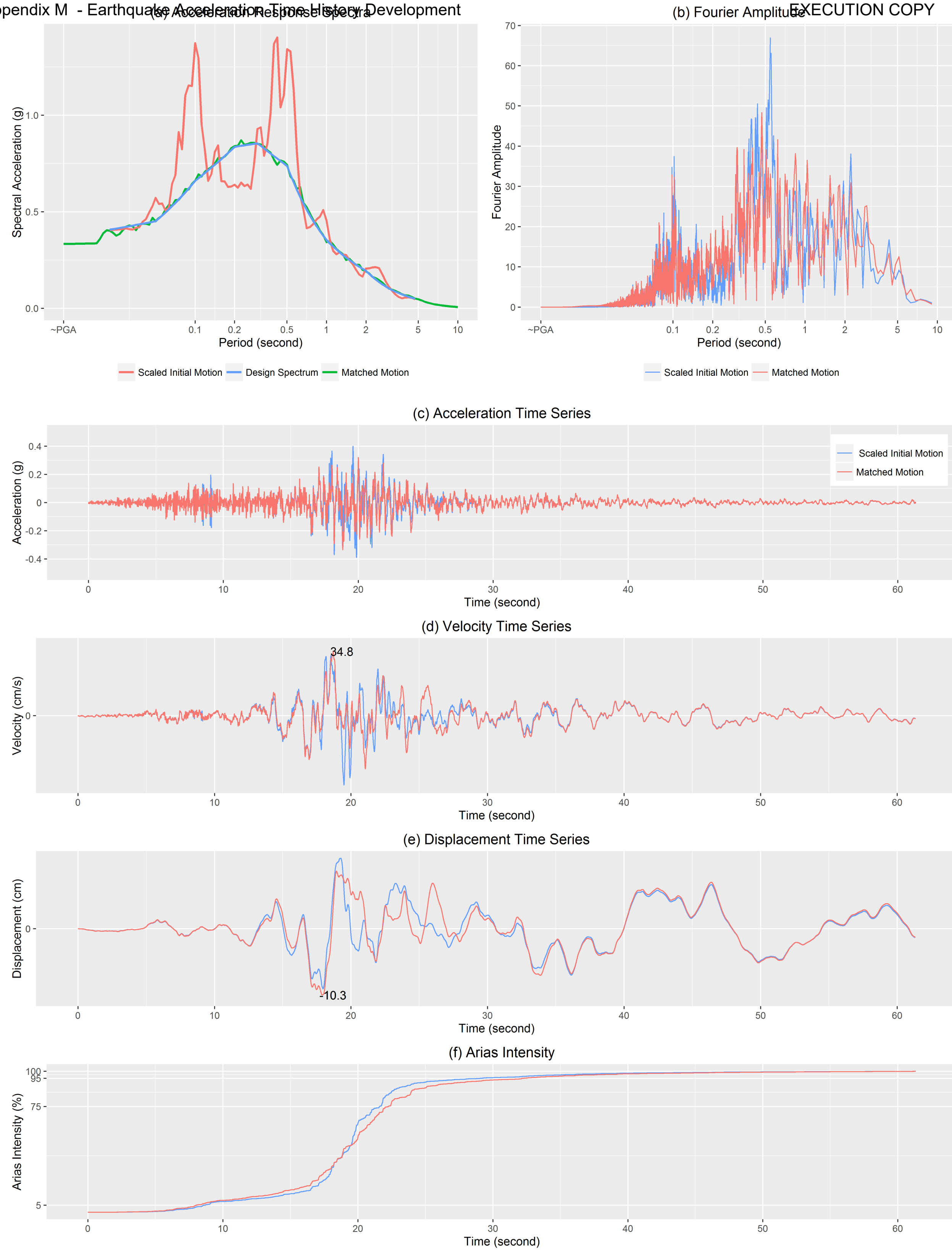
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, DB, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A90

2018-11-27 16:28:45 FLi



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

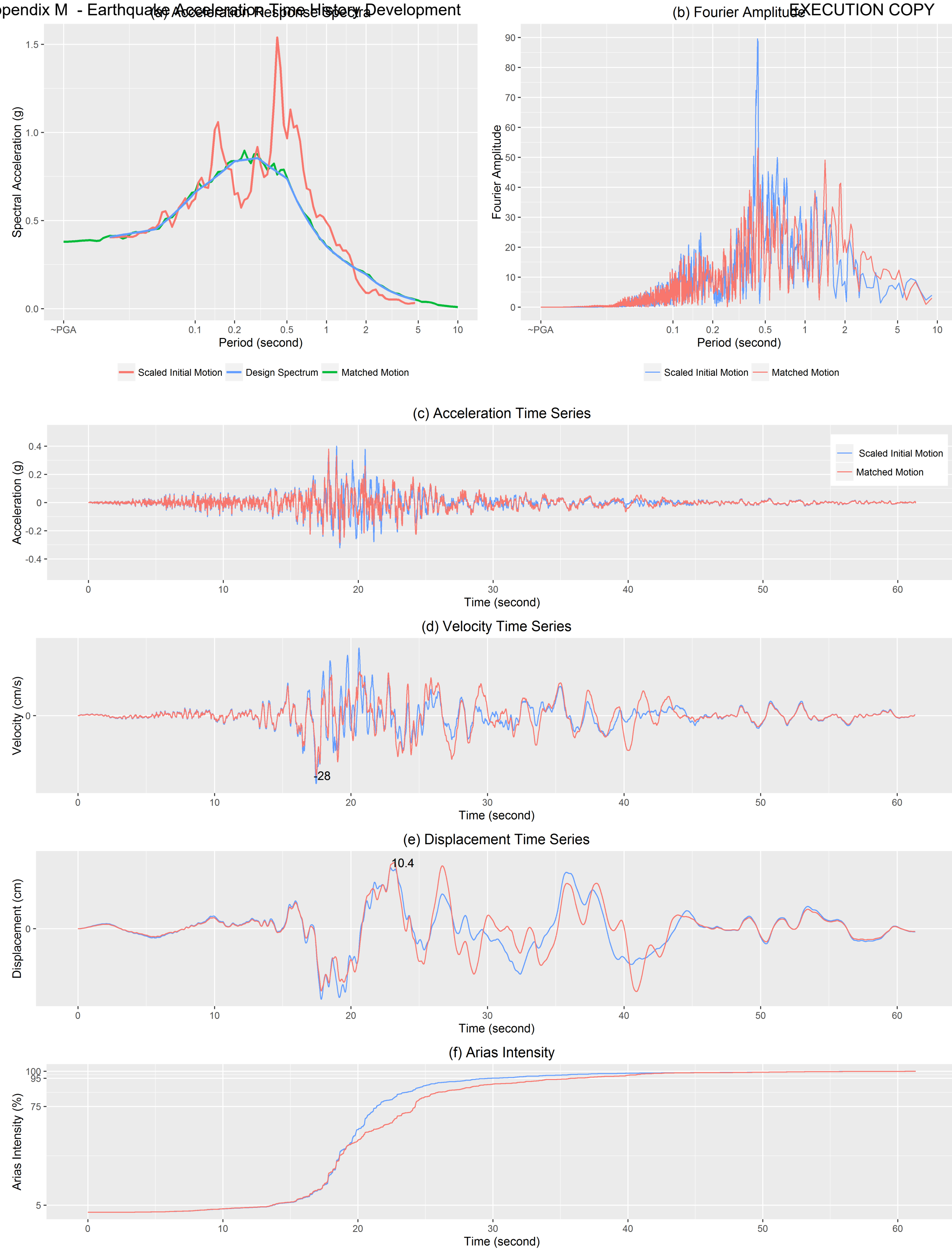
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 180)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A91

2018-11-27 16:28:53 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

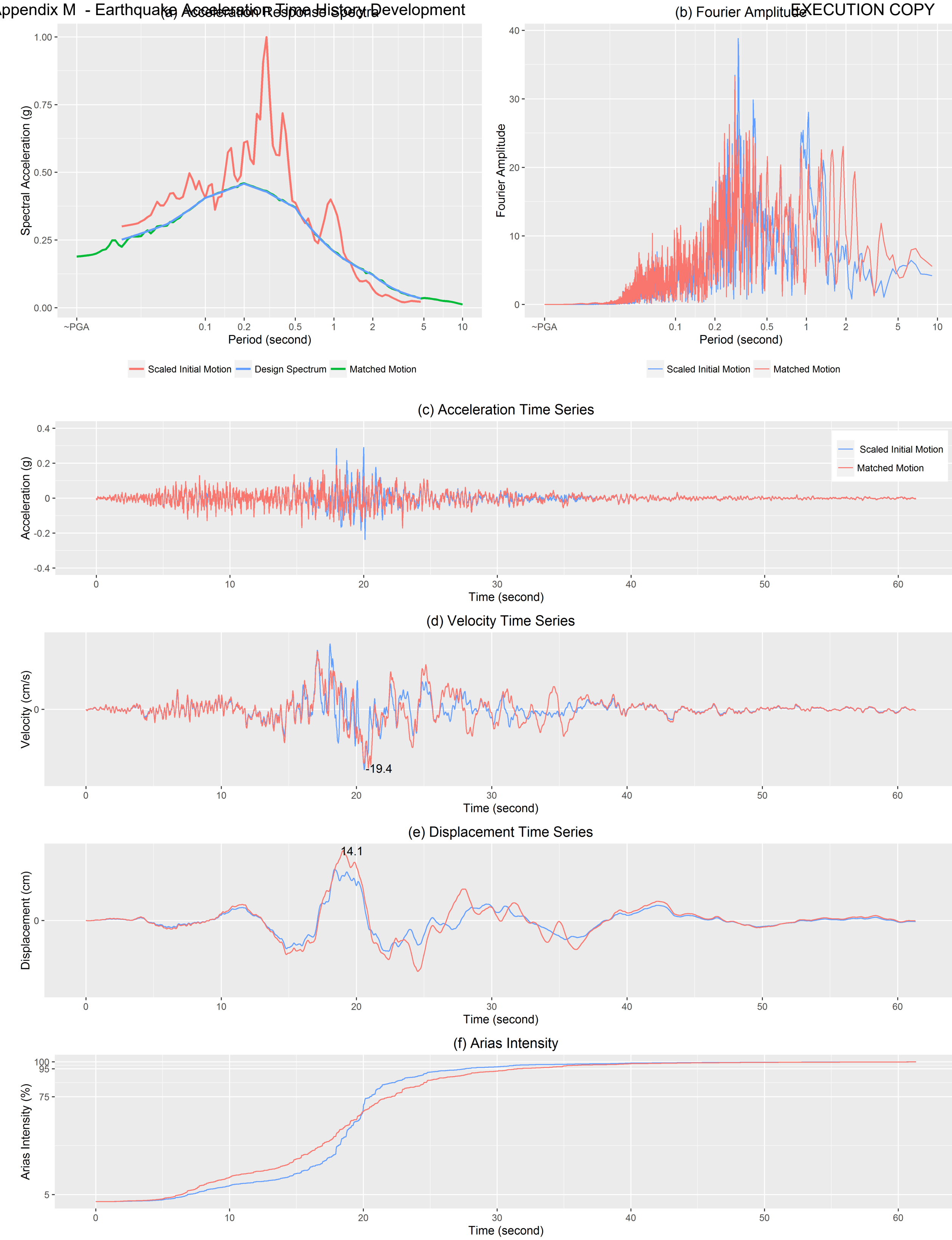
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, 90)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A92



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT

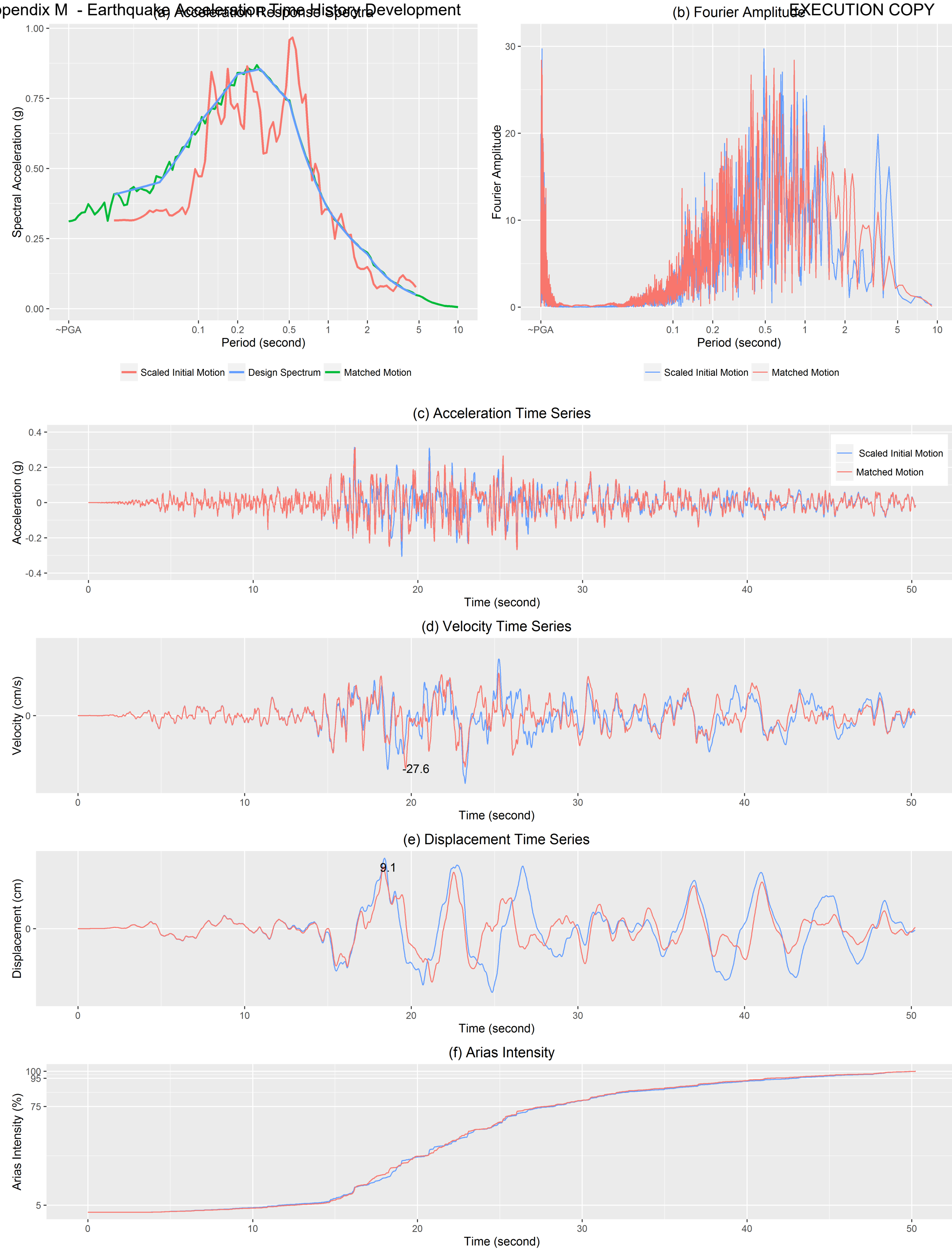
ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD EL SALVADOR (2001, RF, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A93

2018-11-27 16:29:09 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

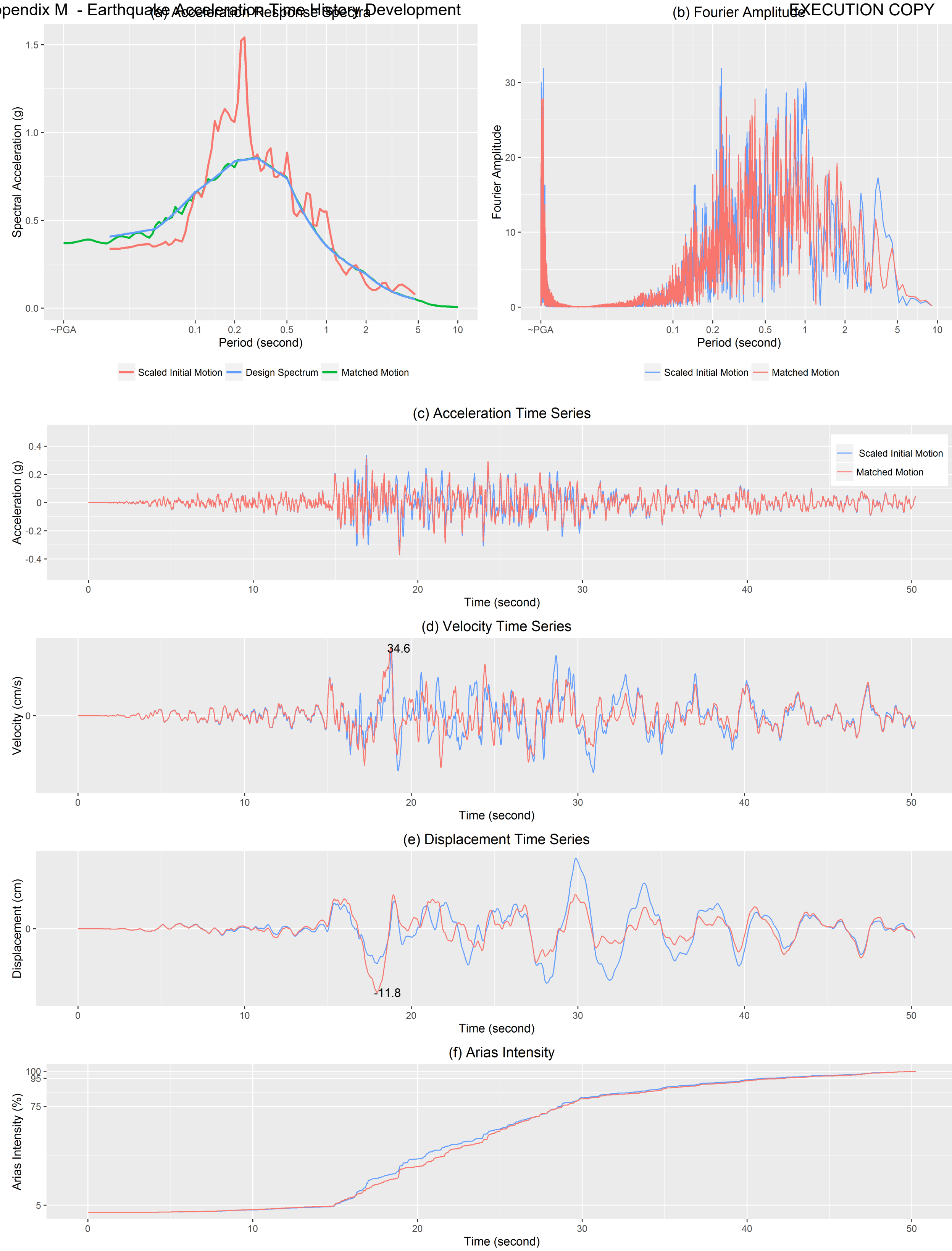
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A94

2018−11−27 16:29:16 FL



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

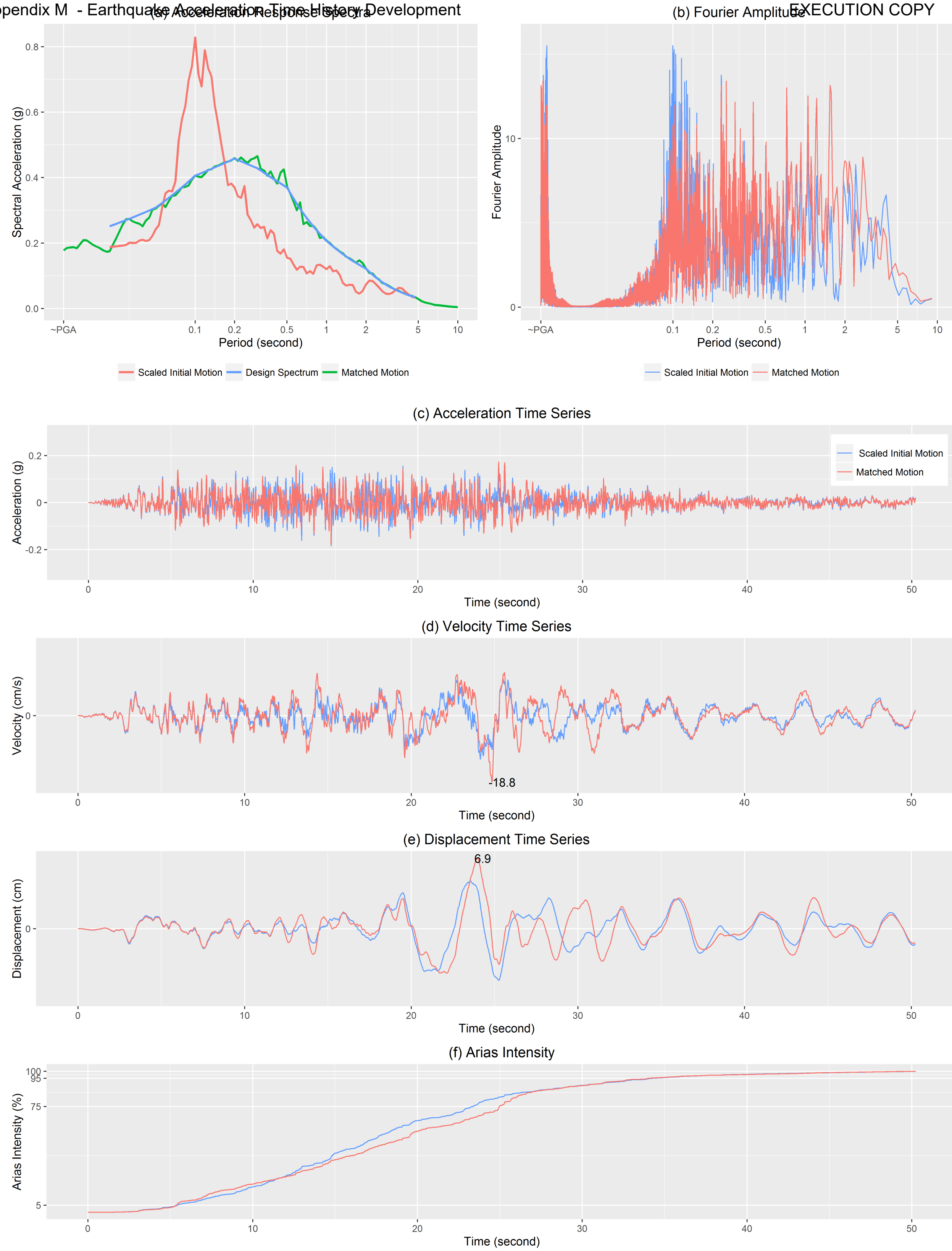
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A95

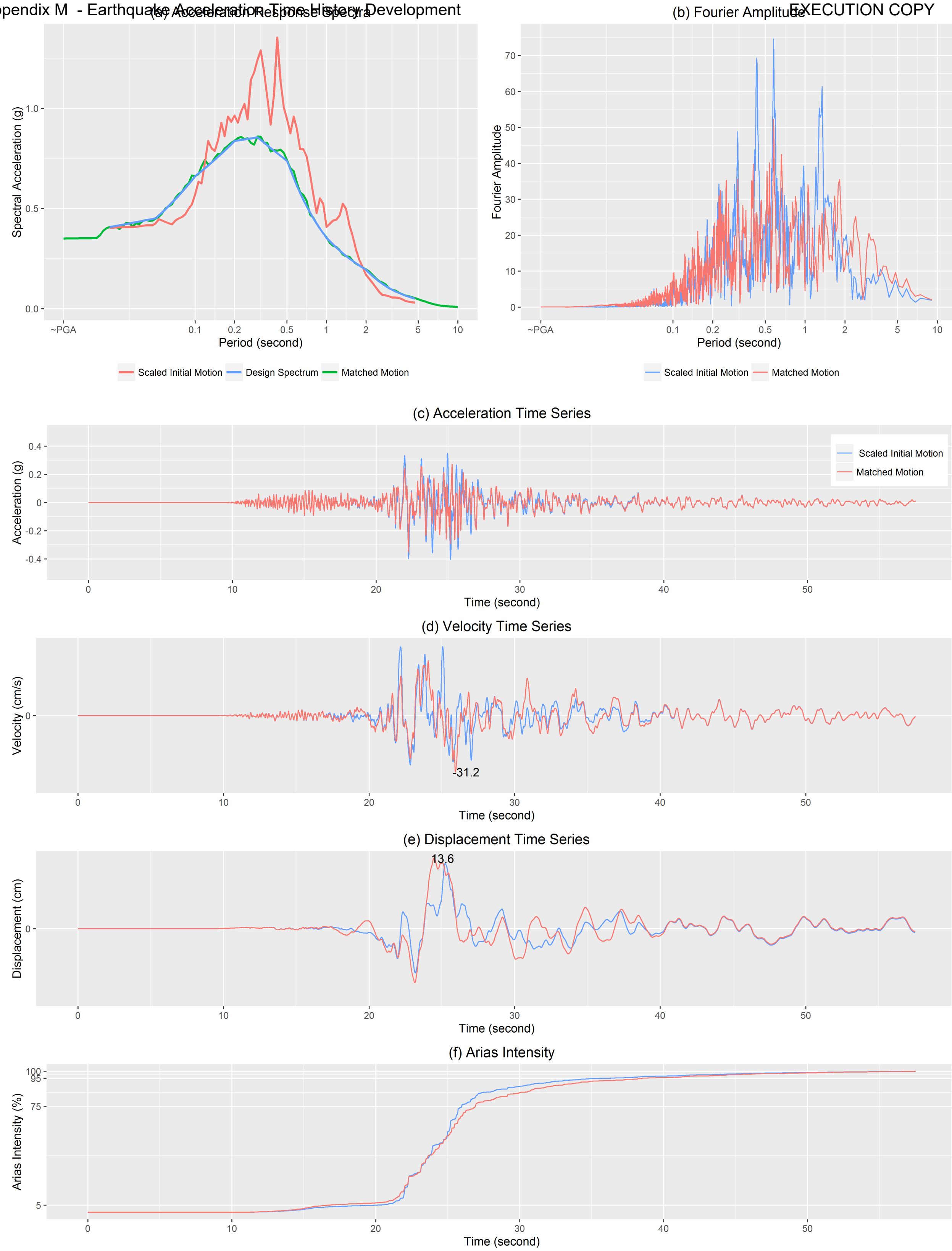


CLIENT **STANTEC CONSULTANTS INC.**	PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**
CONSULTANT GOLDER	TITLE **SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD MIYAGI (2005, MYG006, UD)**

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A96

2018-11-27 16:29:32 FLI



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

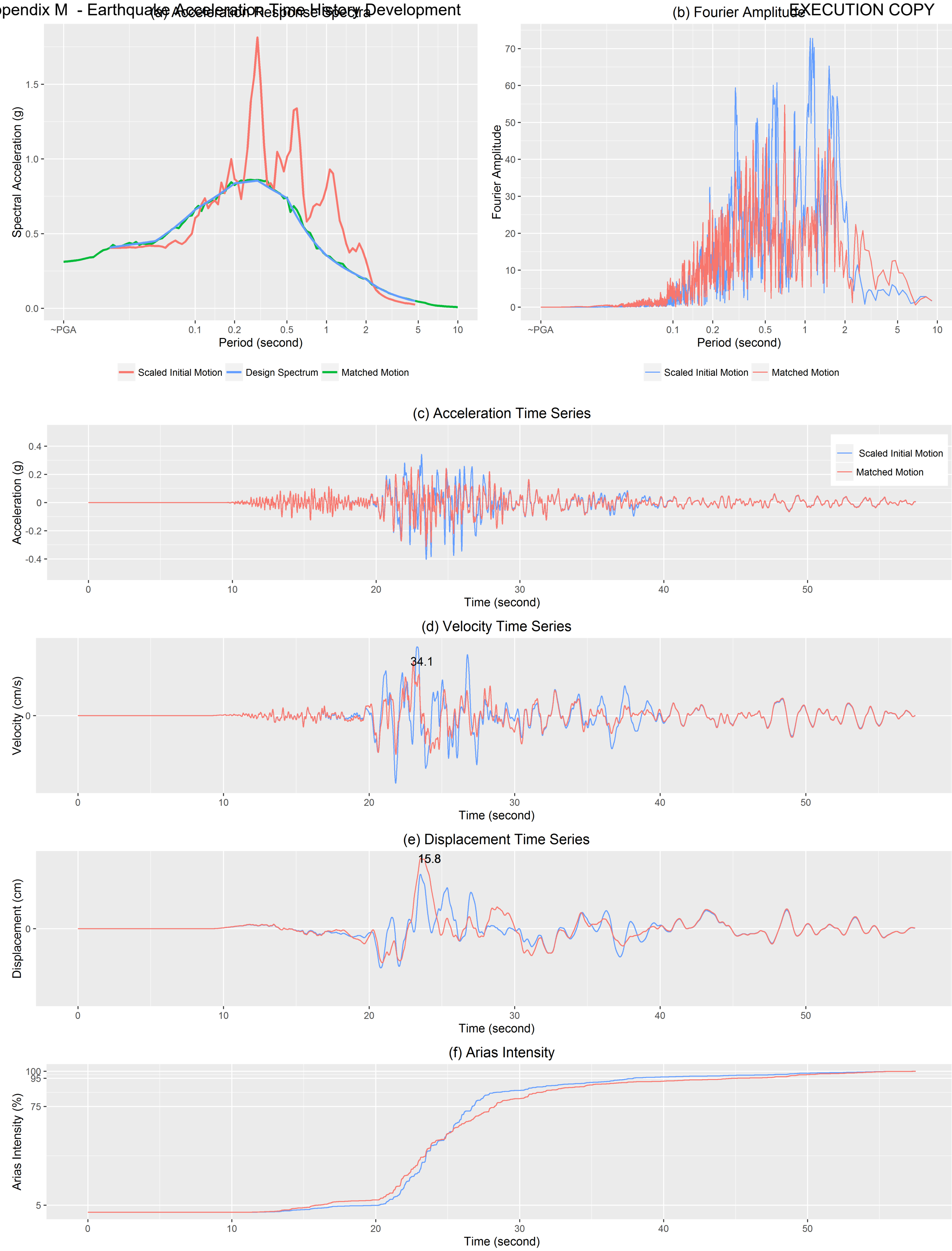
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 125)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A97

2018-11-27 16:29:40 FL



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

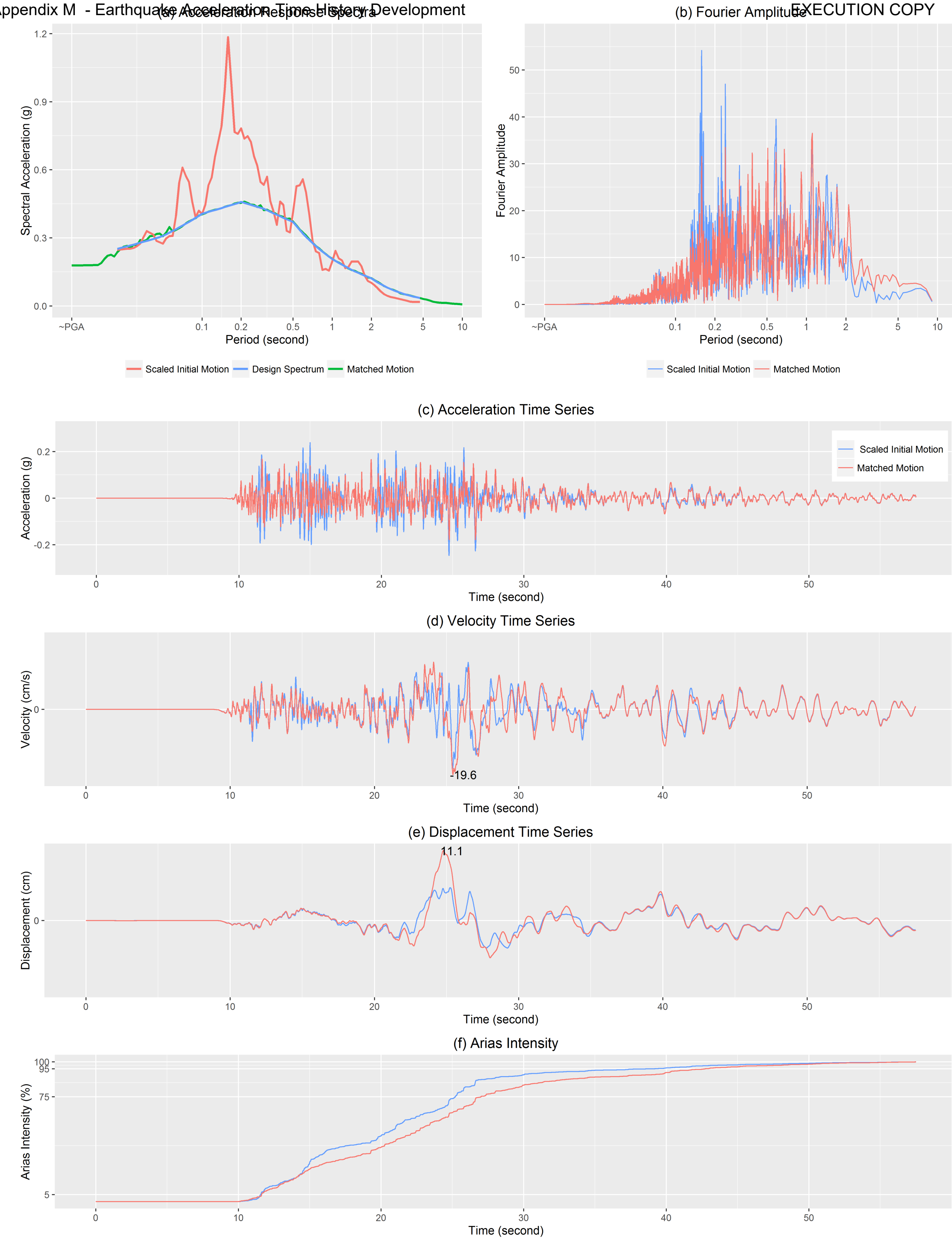
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, 215)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A98

2018-11-27 16:29:48 FLi



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

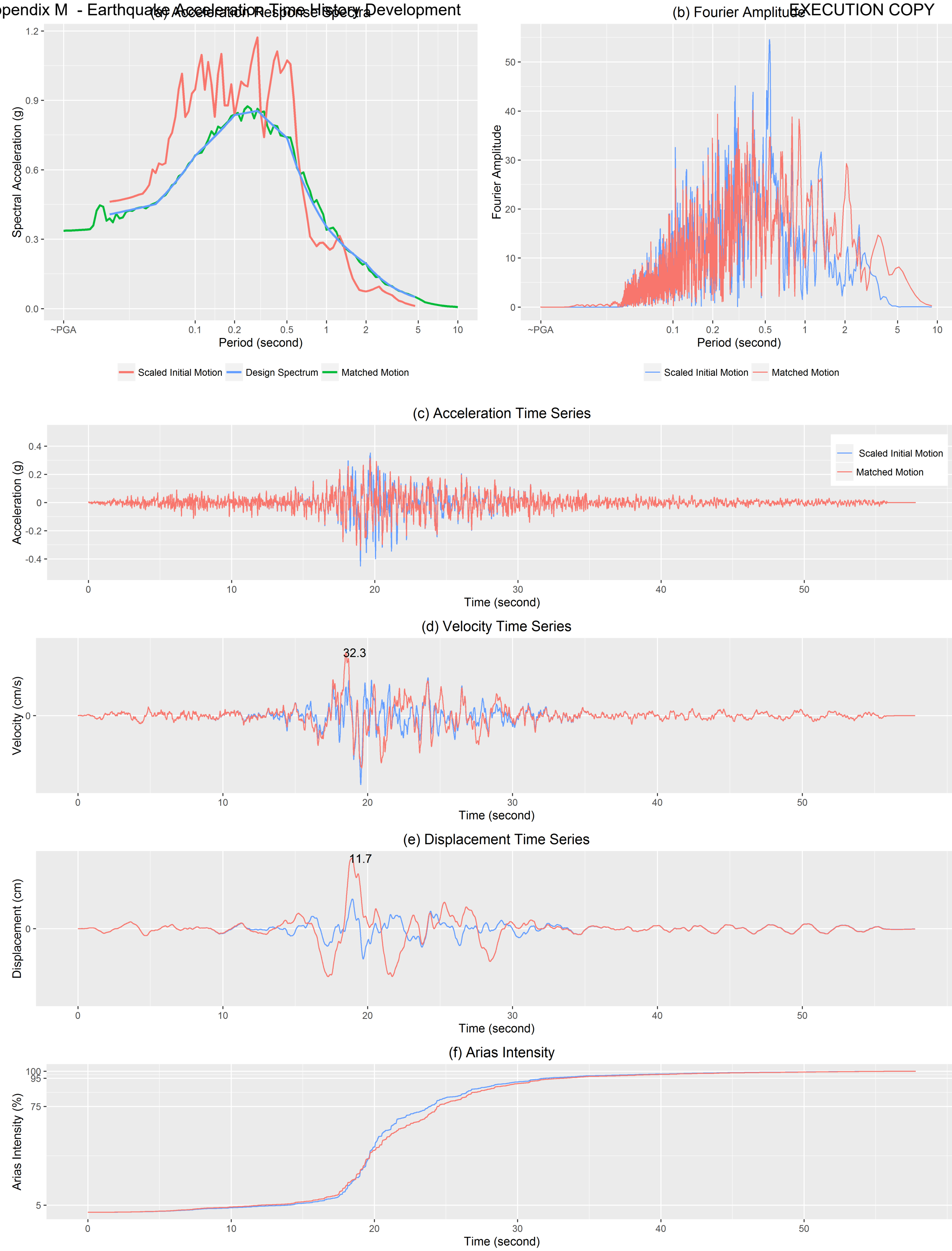
GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD NISQUALLY (2001, 7032−1416, UP)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A99



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

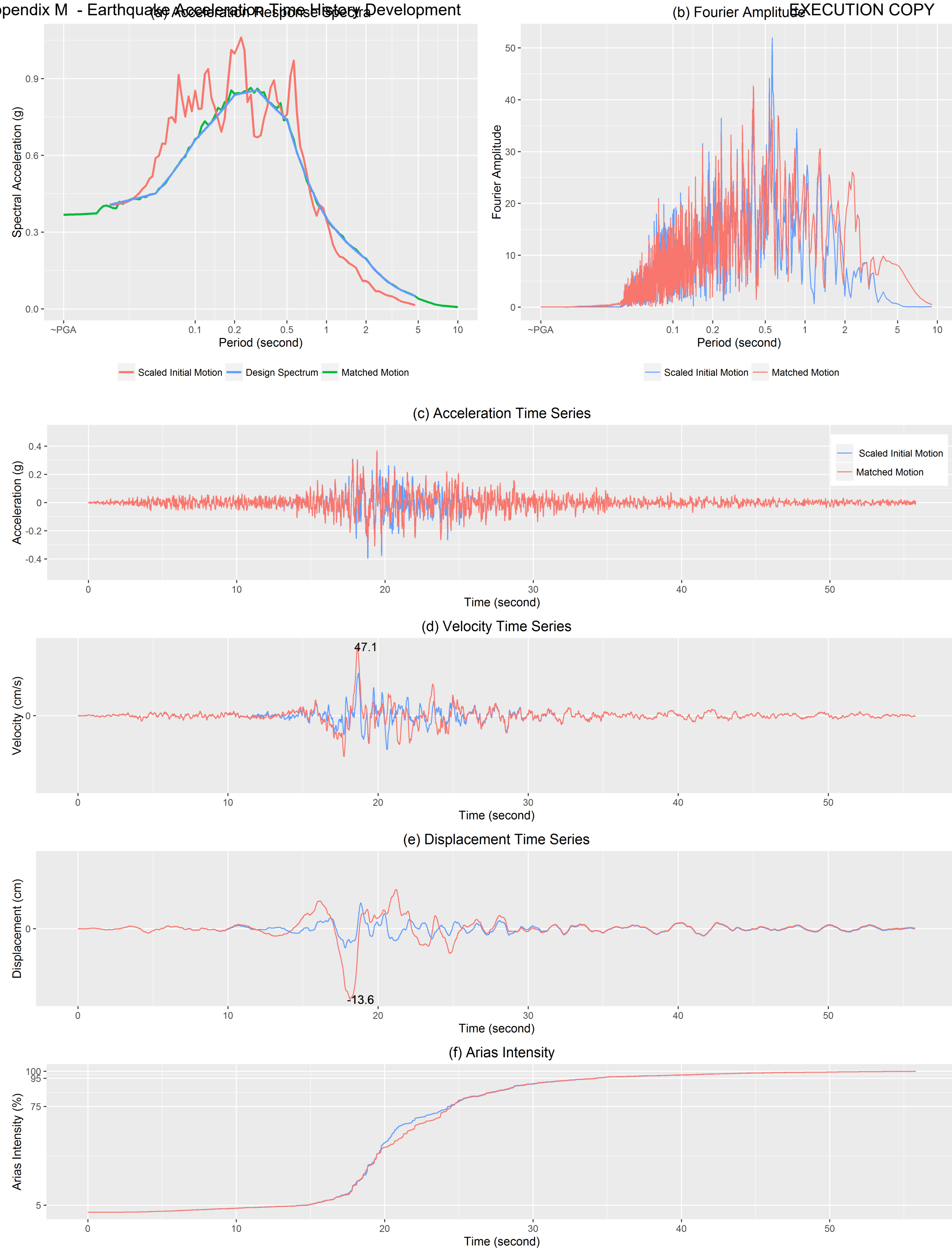
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, L)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A100

2018−11−27 16:30:04 FL



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

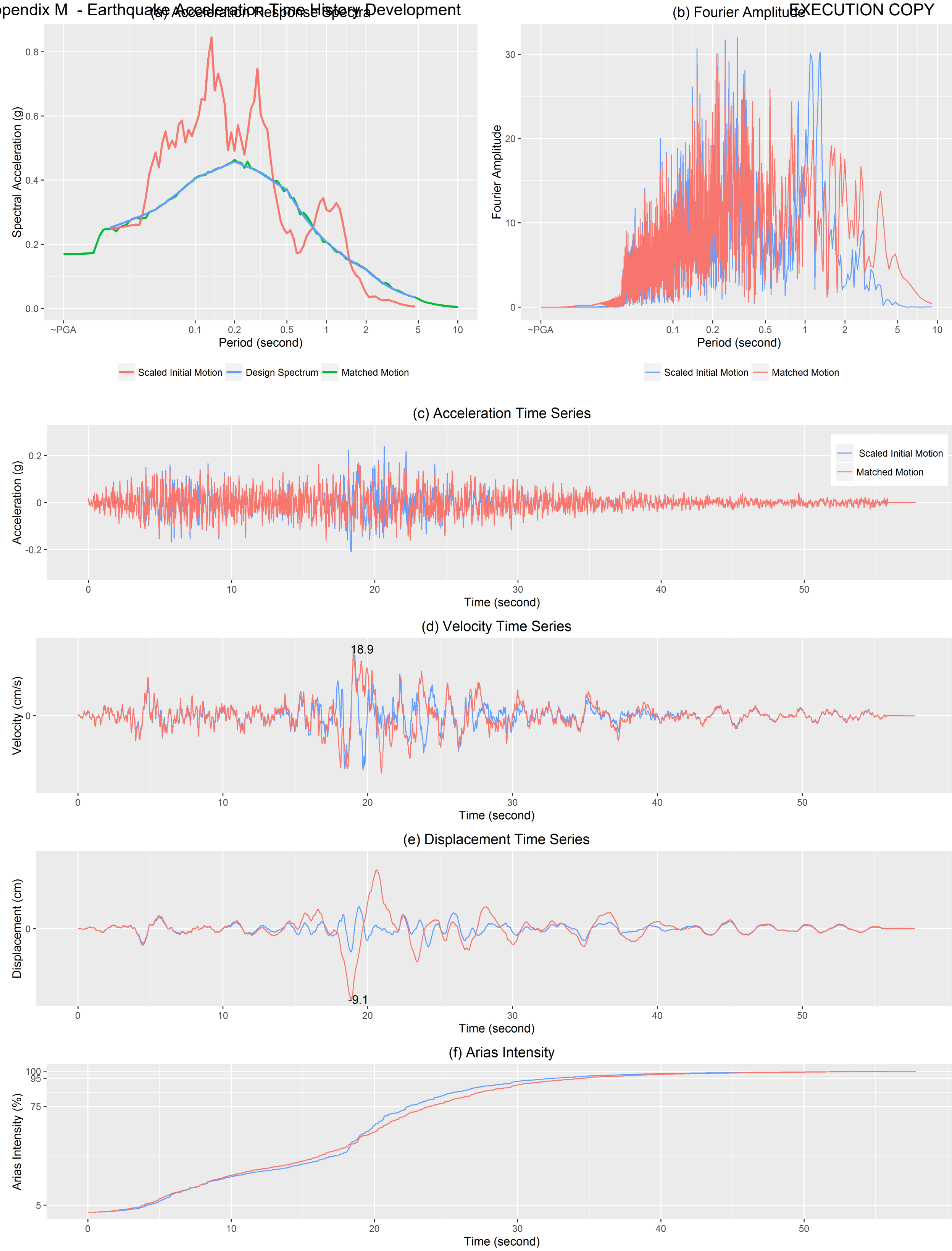
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, T)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A101

2018-11-27 16:30:12 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

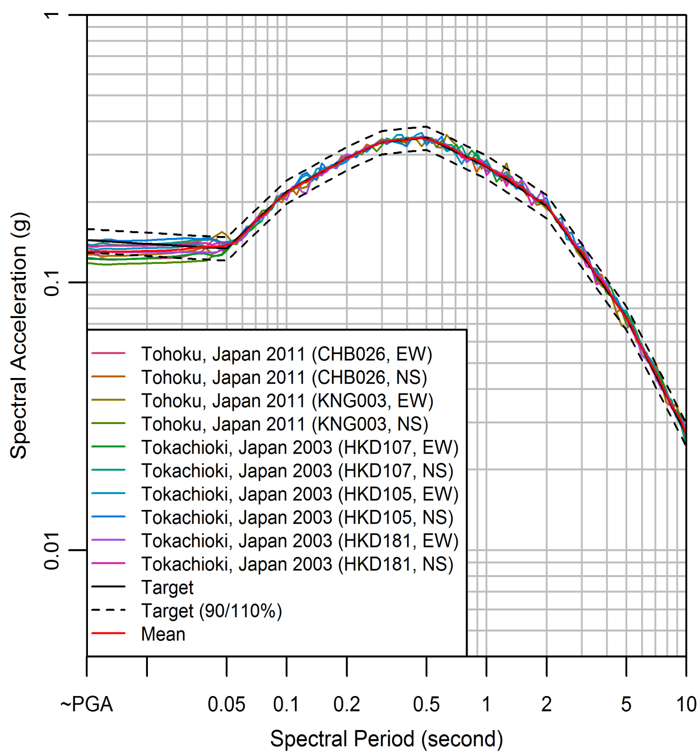
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

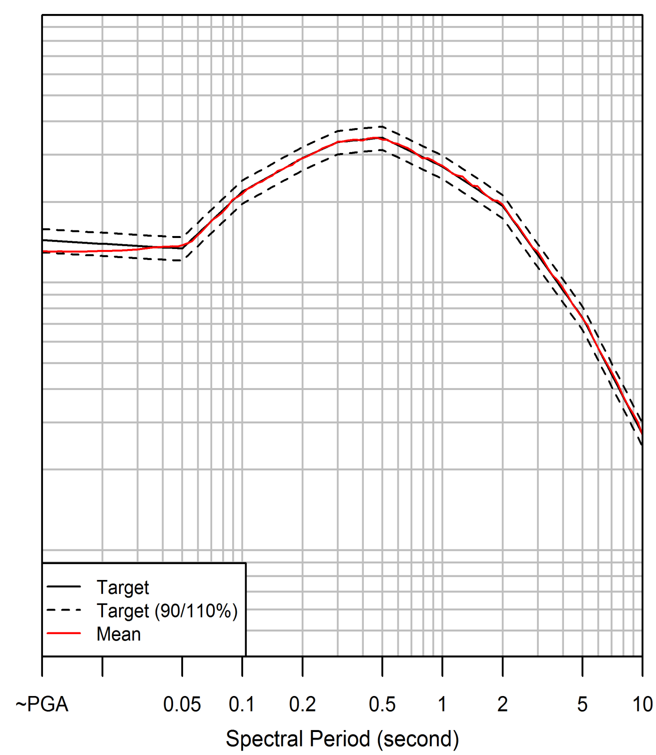
TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TARAPACA (2005, IQUIQUE IDIEM, V)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A102

2018-11-27 16:30:20 FLi





CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

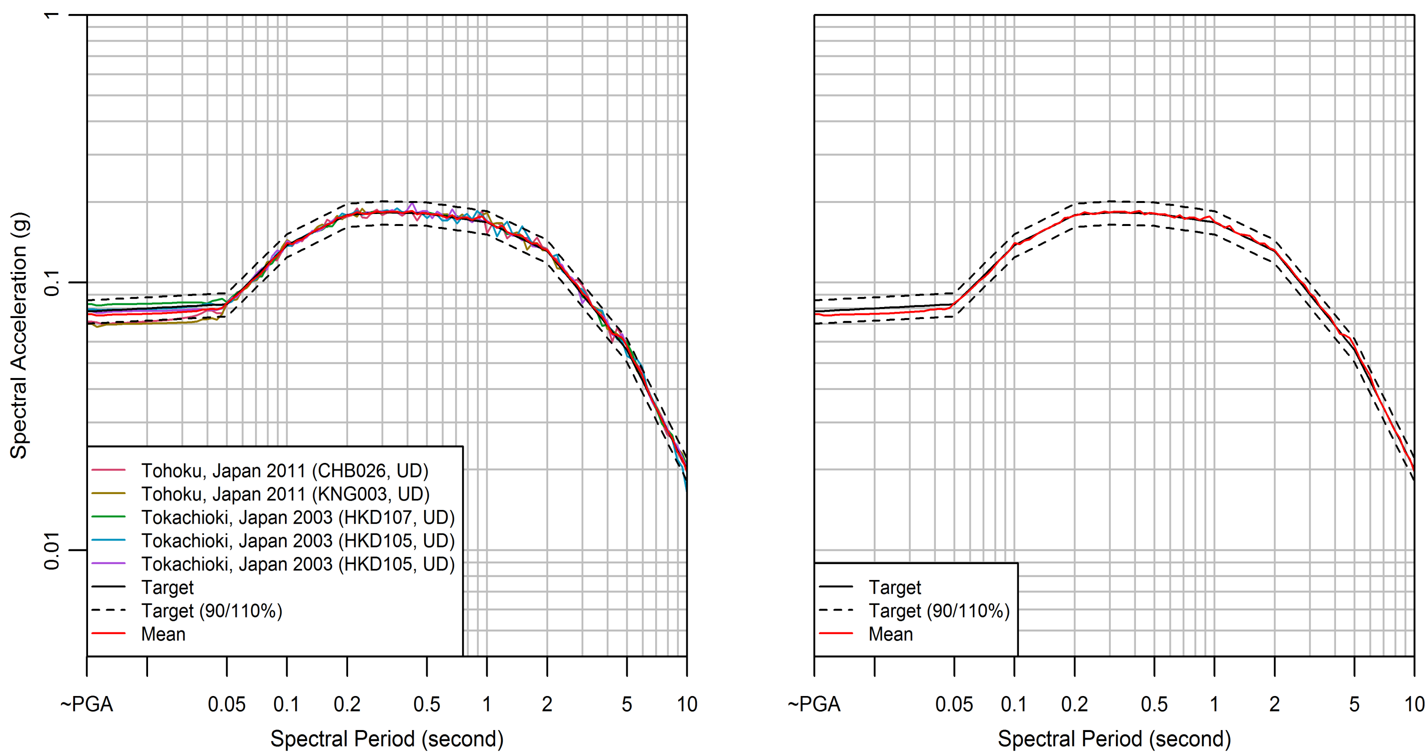
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF HORIZONTAL INTERFACE TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A103

2018−11−27 16:30:27 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

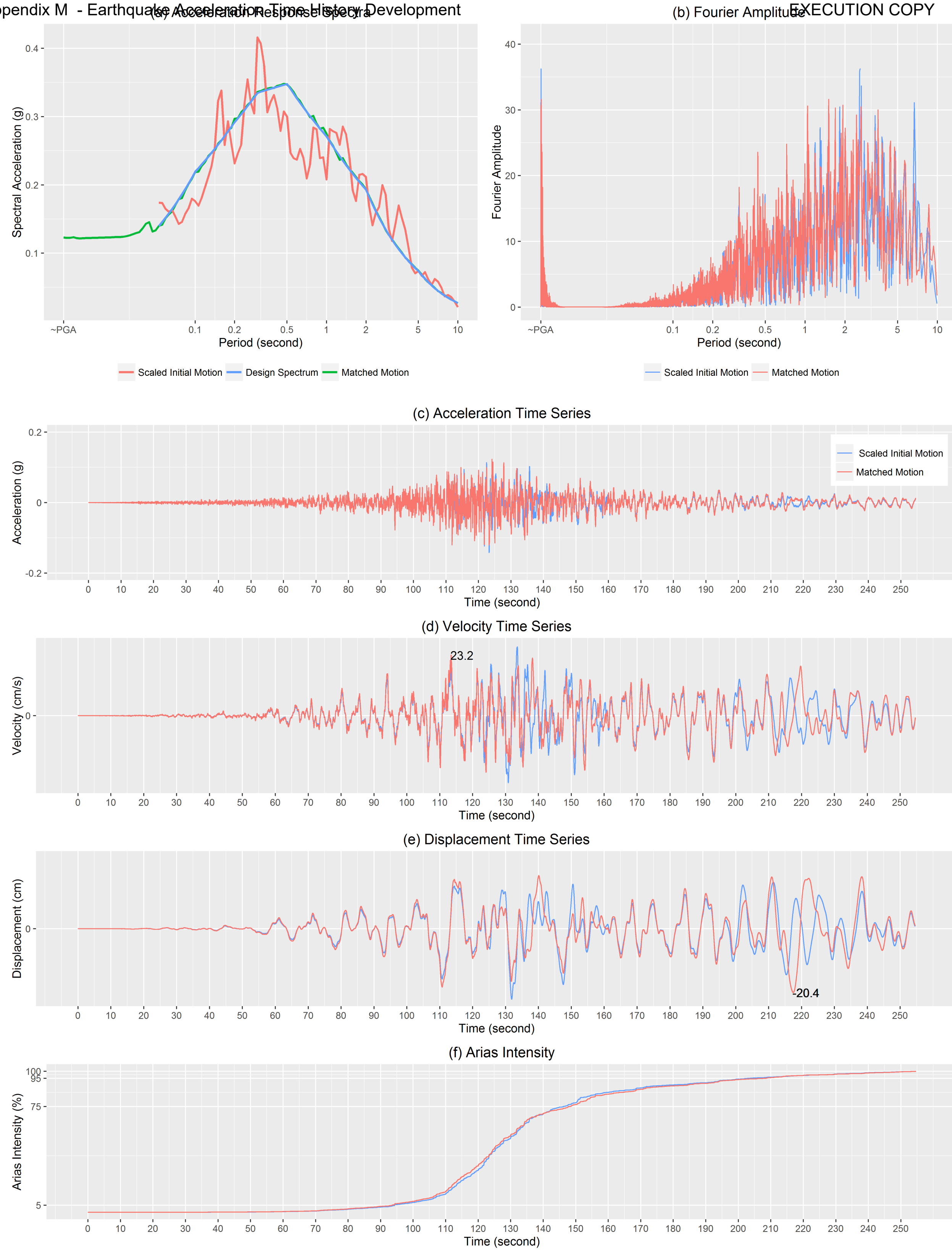
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

COMPARISON OF VERTICAL INTERFACE TARGET SPECTRUM AND RESPONSE SPECTRA OF SPECTRALLY−MATCHED ACCELERATION TIME HISTORIES FOR THE 2475−YEAR RETURN PERIOD

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A104

2018−11−27 16:30:30 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

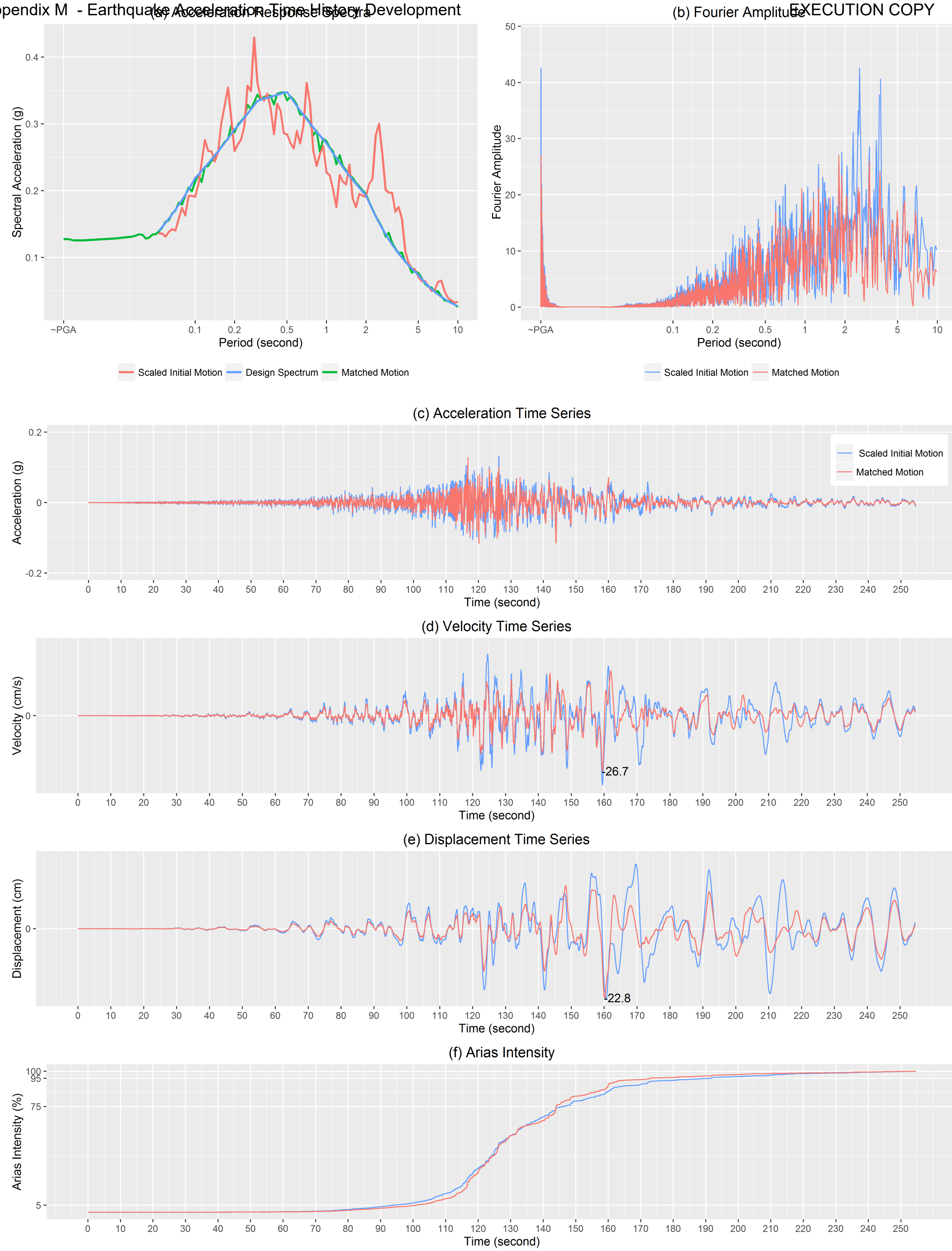
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, CHB026, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A105

2018-11-27 16:30:33 FLI

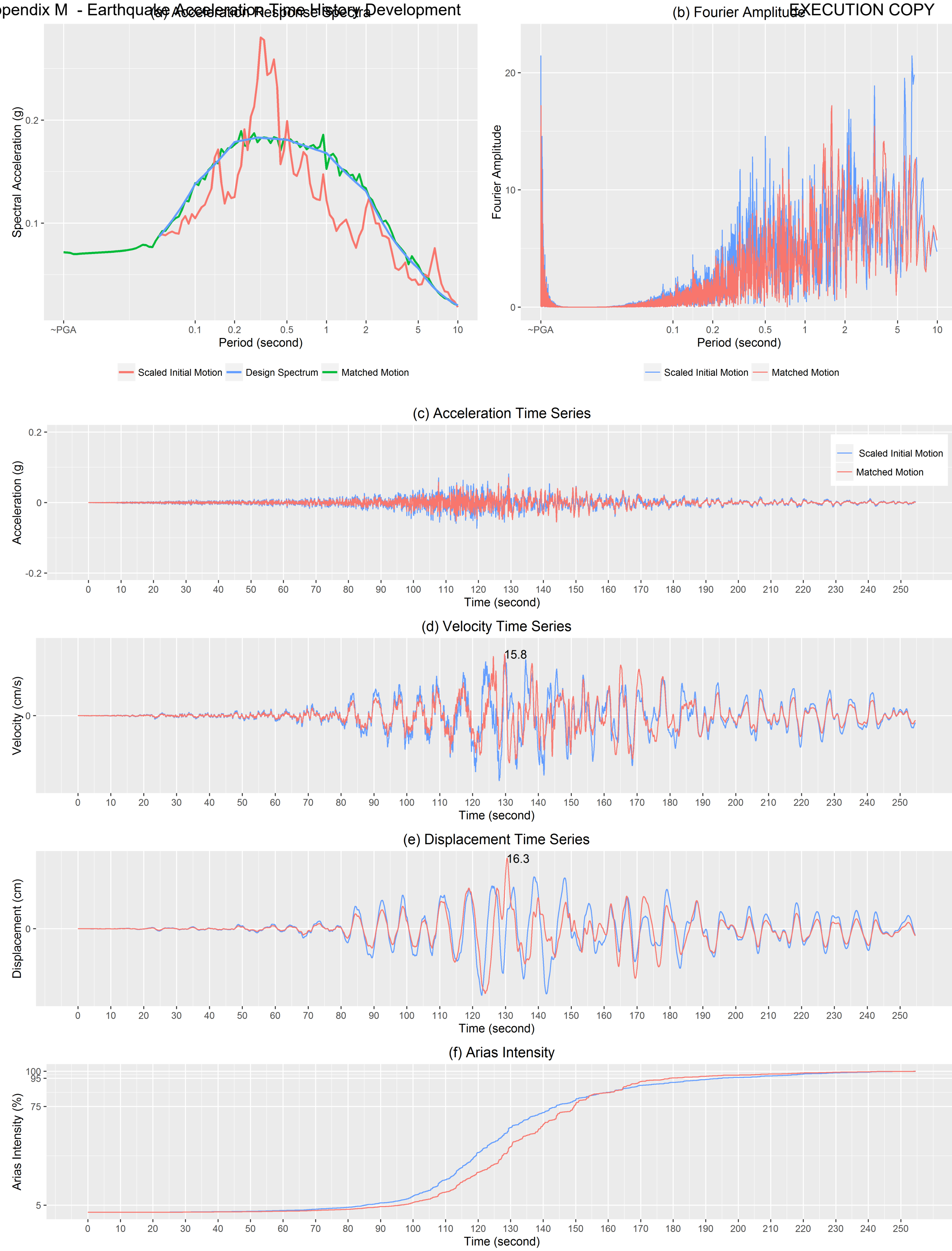


CLIENT **STANTEC CONSULTANTS INC.**	PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**
CONSULTANT GOLDER	TITLE **SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, CHB026, NS)**

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A106

2018-11-27 16:30:40 FL



CLIENT

STANTEC CONSULTANTS INC.

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

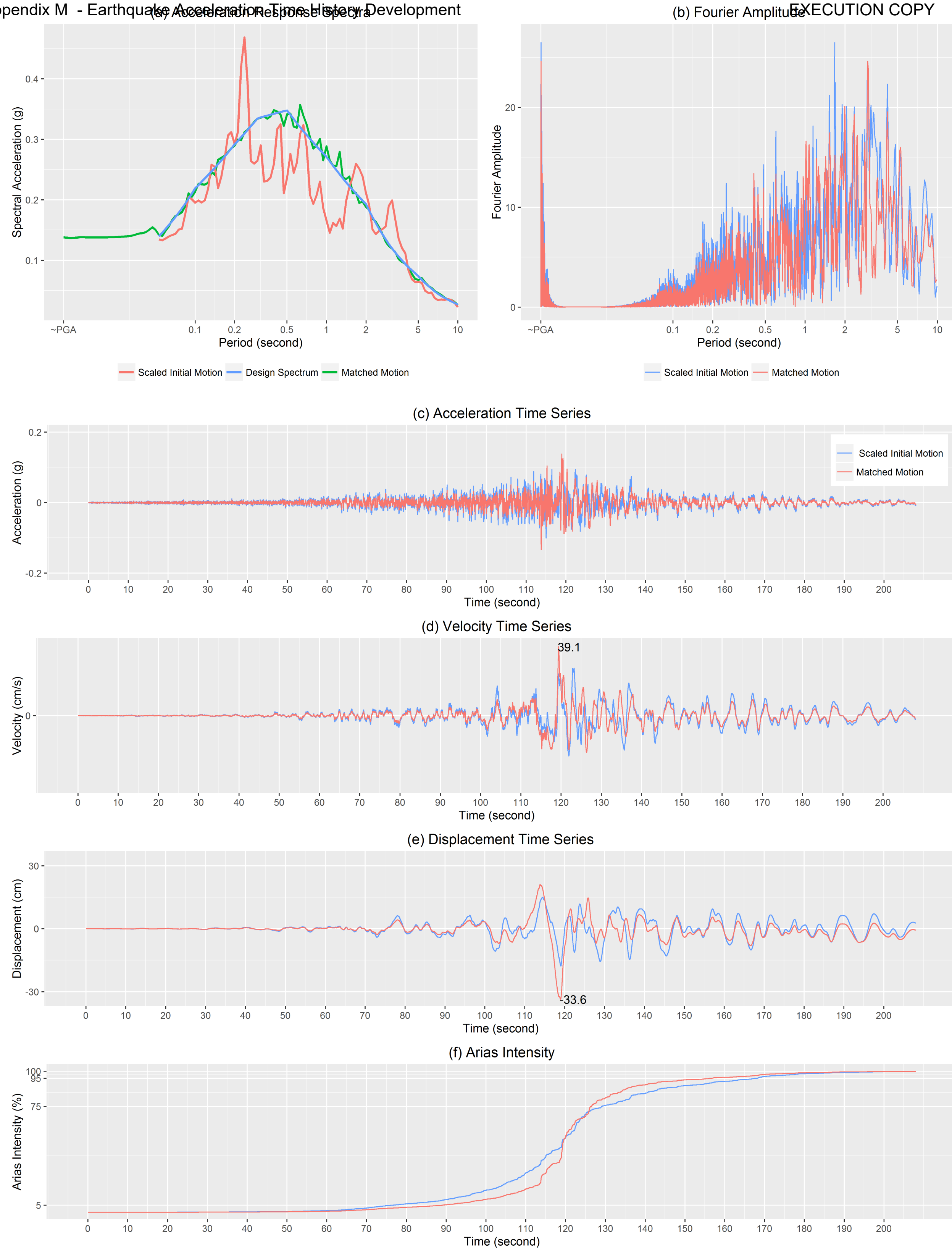
PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, CHB026, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A107



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

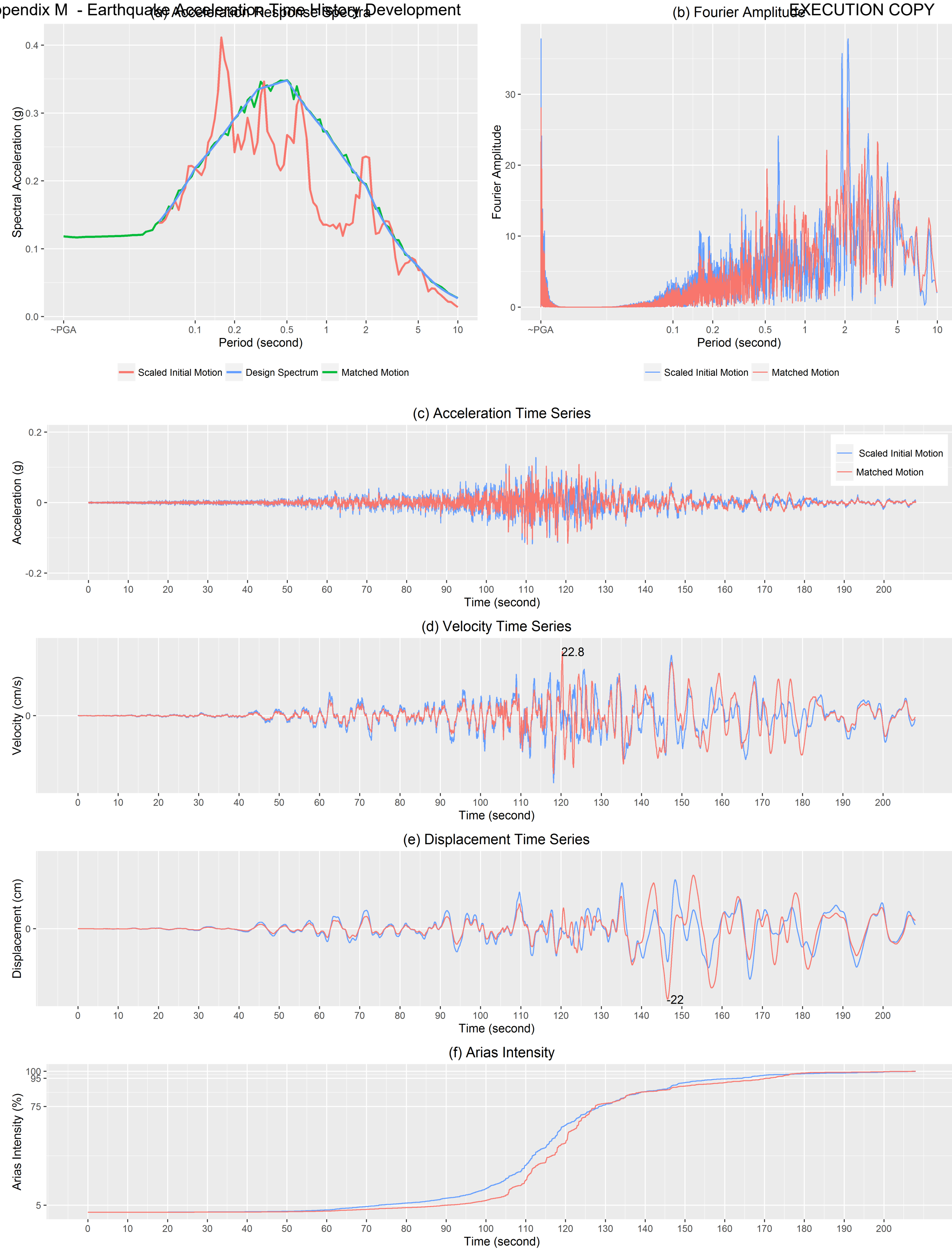
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, KNG003, EW)

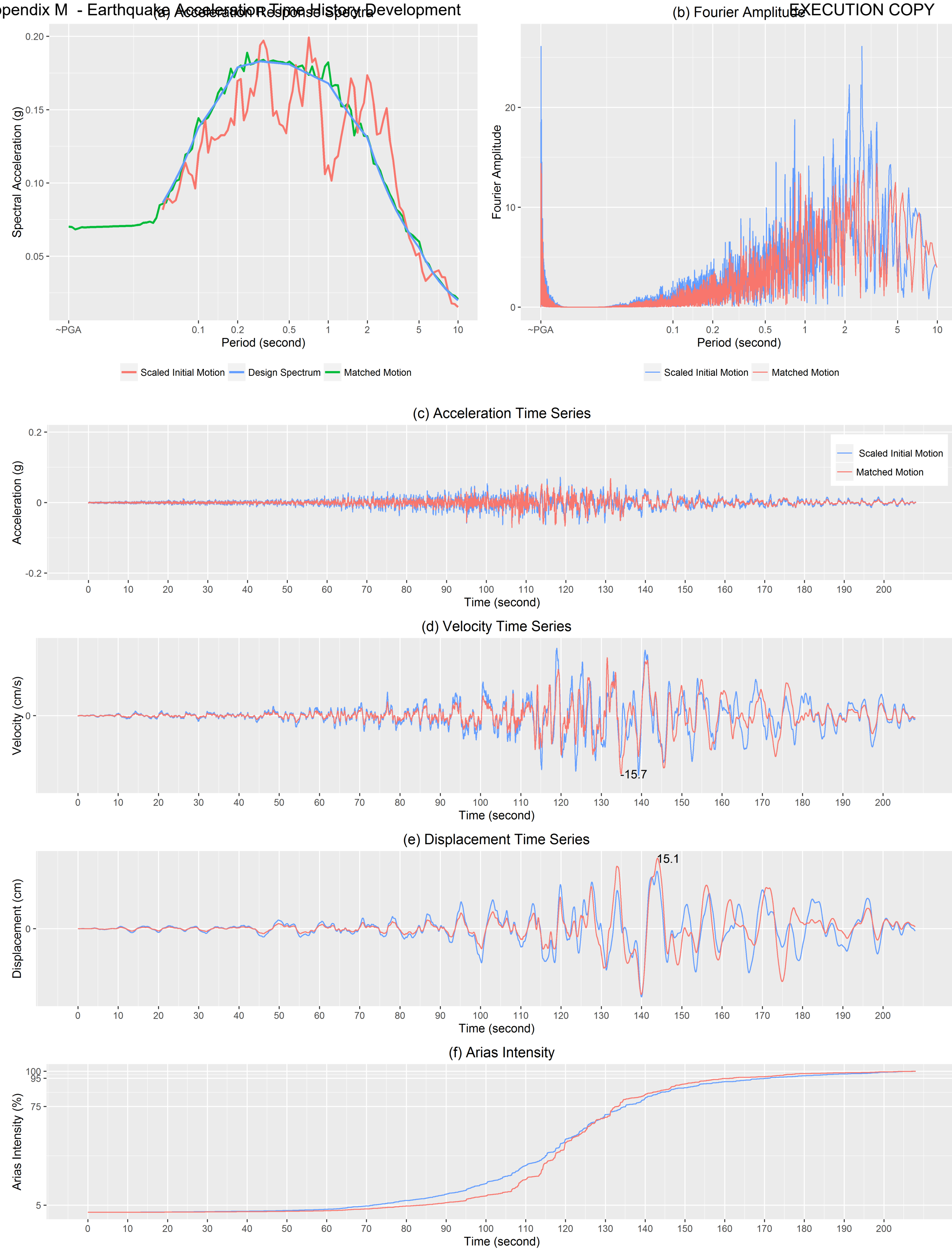
PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A108

2018-11-27 16:30:57 FL



CLIENT		PROJECT			
STANTEC CONSULTANTS INC.		**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**			
CONSULTANT	DD/MM/YYYY 11/27/2018	TITLE			
GOLDER	PREPARED AR	**SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, KNG003, NS)**			
	DESIGN AR				
	REVIEW FL	PROJECT No.	PHASE	REV.	FIGURE
	APPROVED AH	1419105	7100	A	A109

2018-11-27 16:31:05 FL



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOHOKU, JAPAN (2011, KNG003, UD)

PROJECT No.	PHASE	REV.	FIGURE
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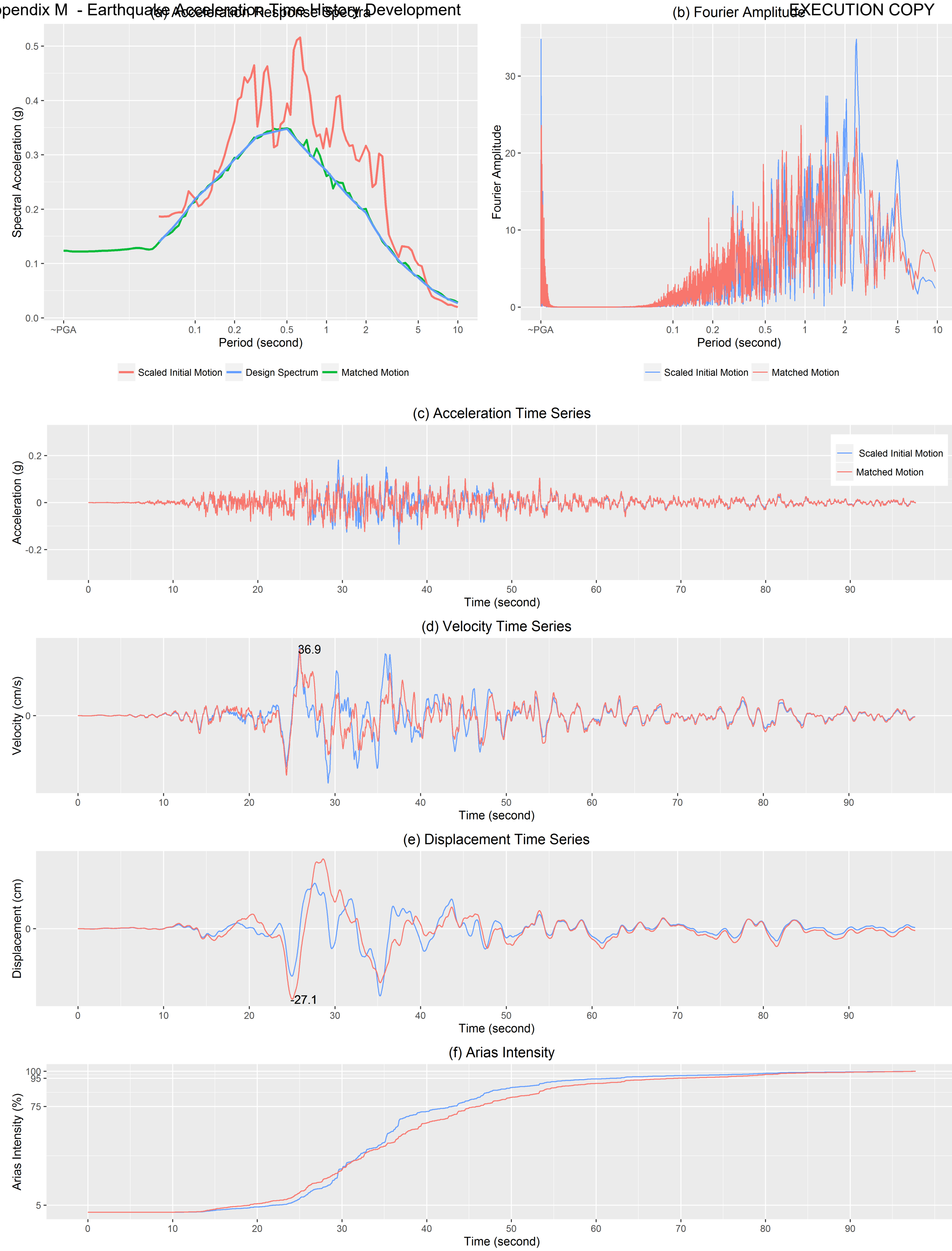
2018-11-27 16:31:13 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

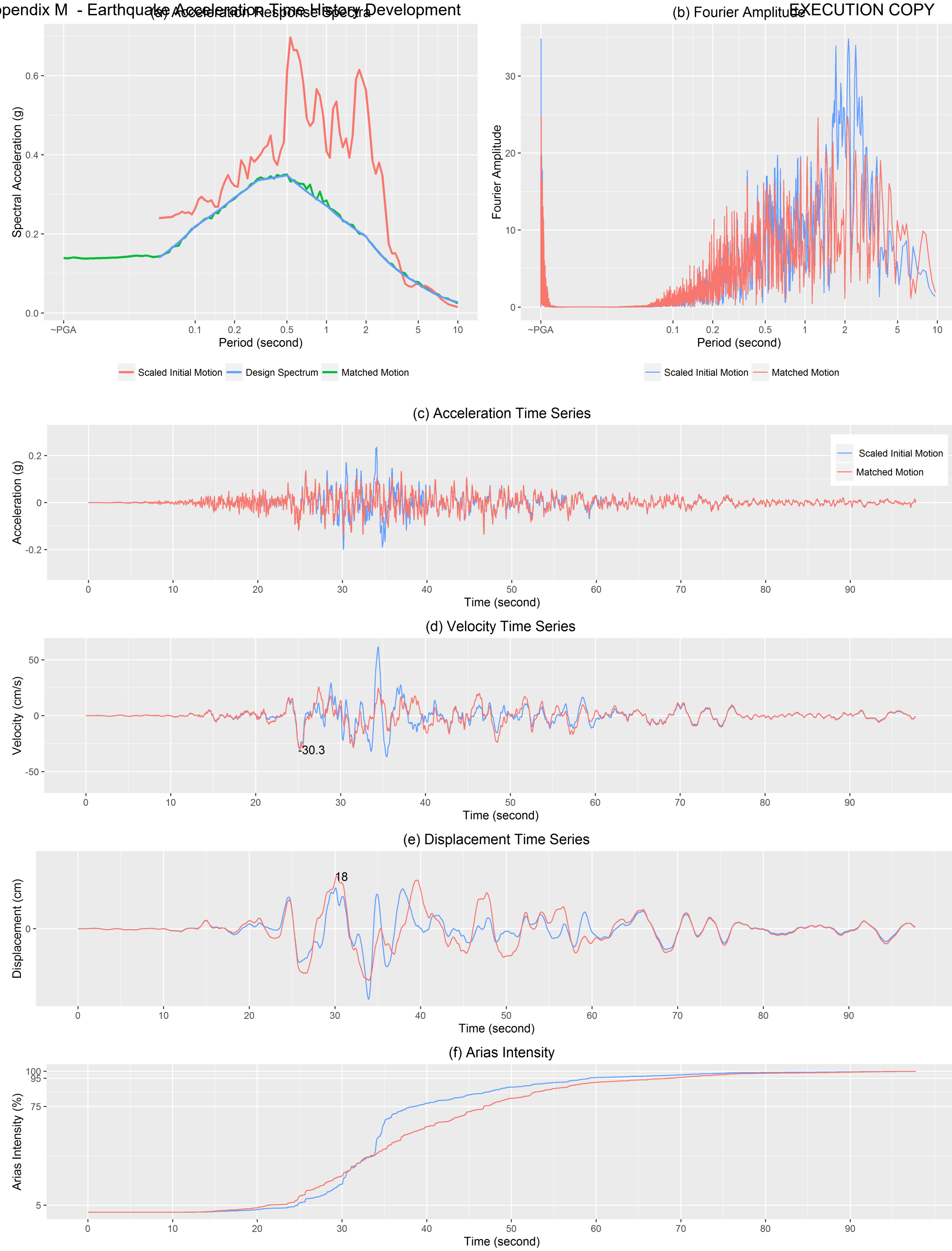
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD107, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A111

2018-11-27 16:31:21 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

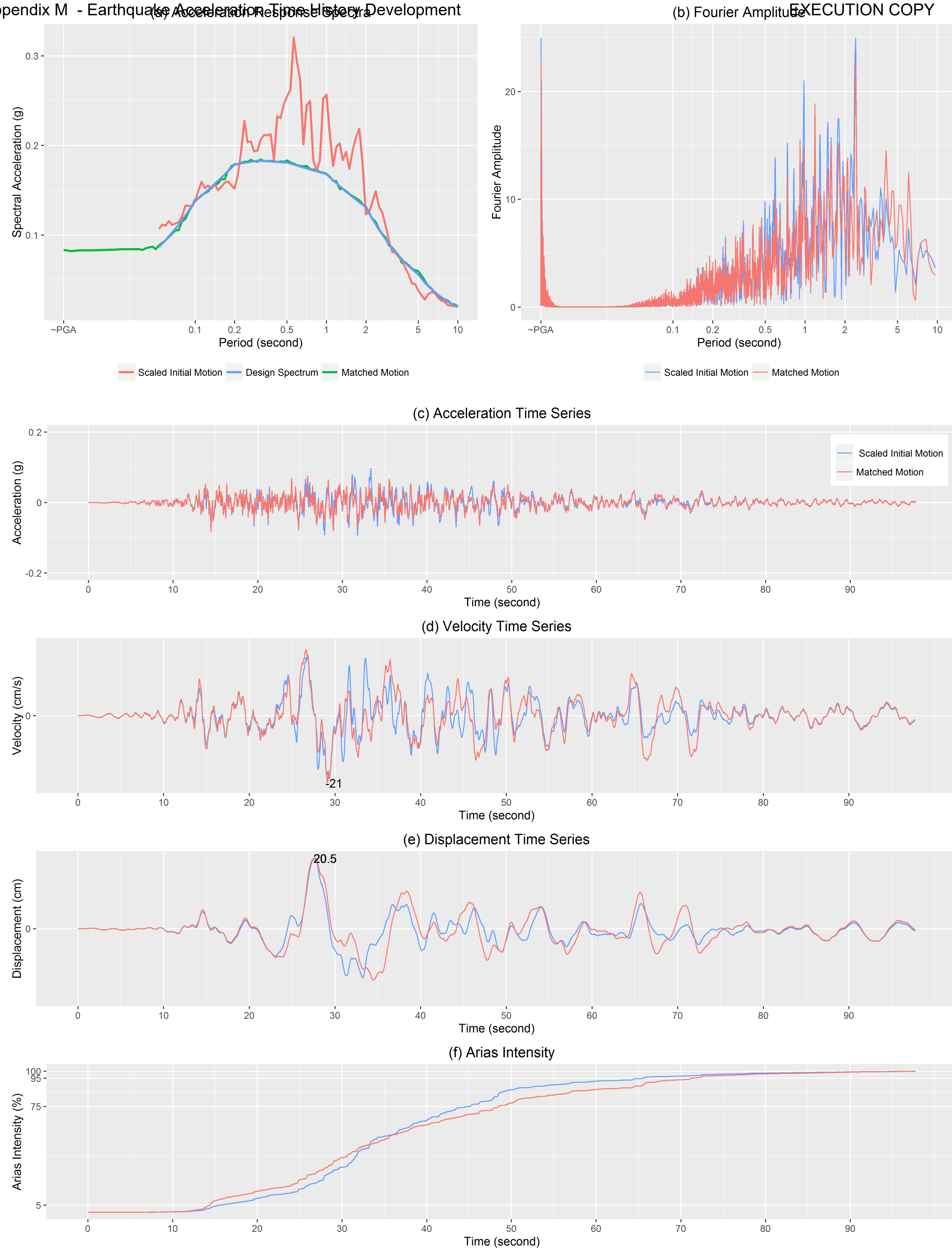
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD107, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A112

2018-11-27 16:31:29 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

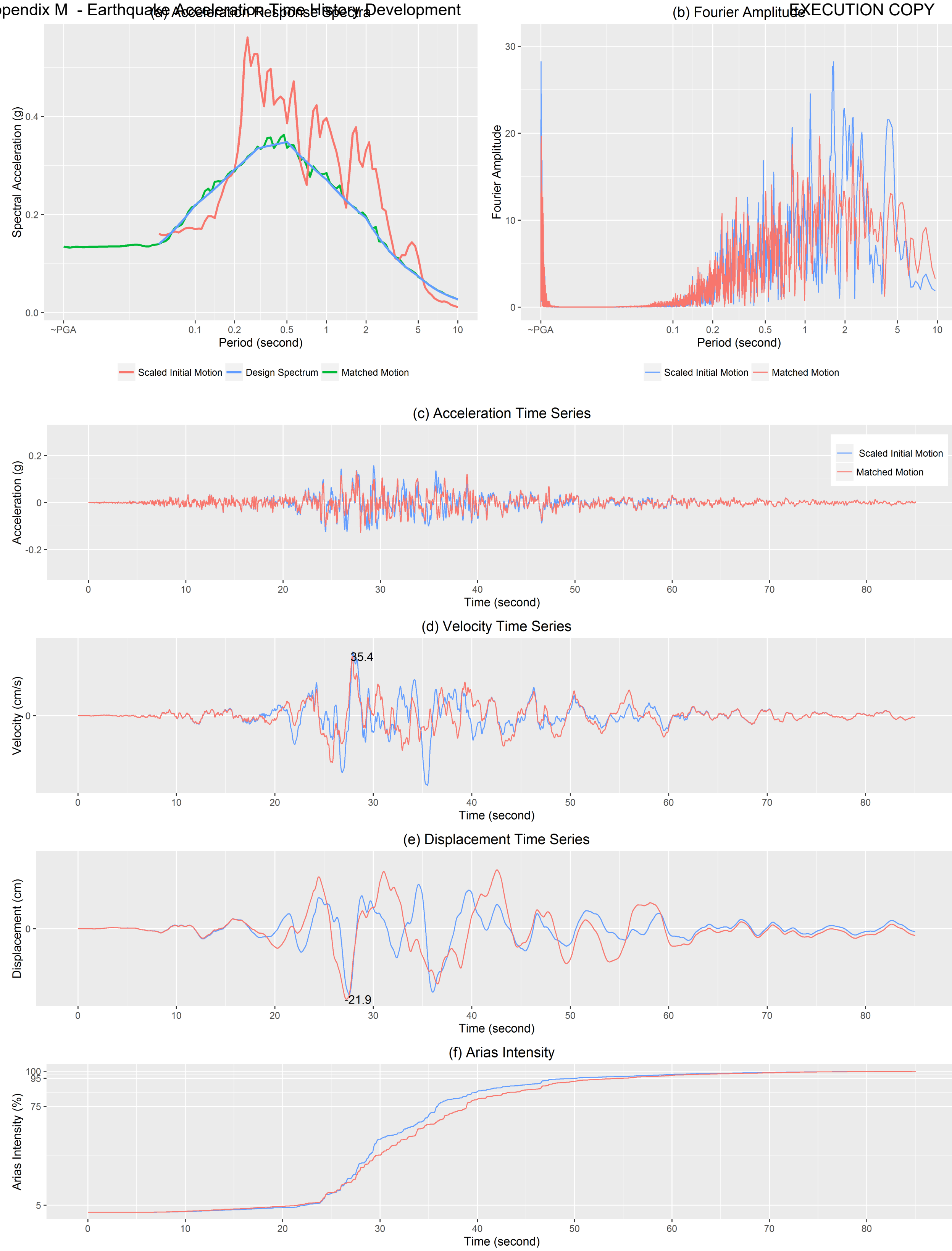
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD107, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A113

2018-11-27 16:31:37 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

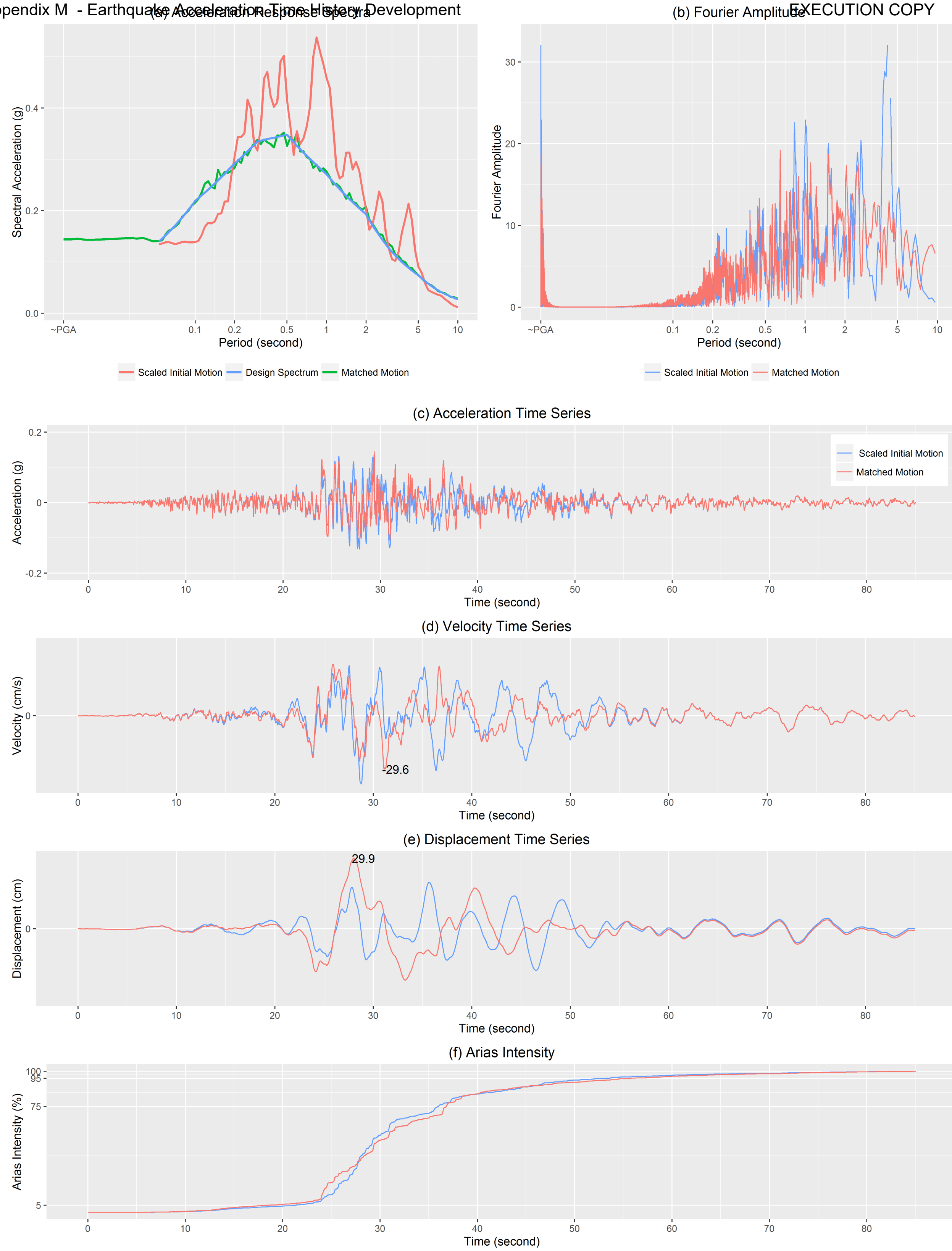
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD105, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A114

2018-11-27 16:31:45 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

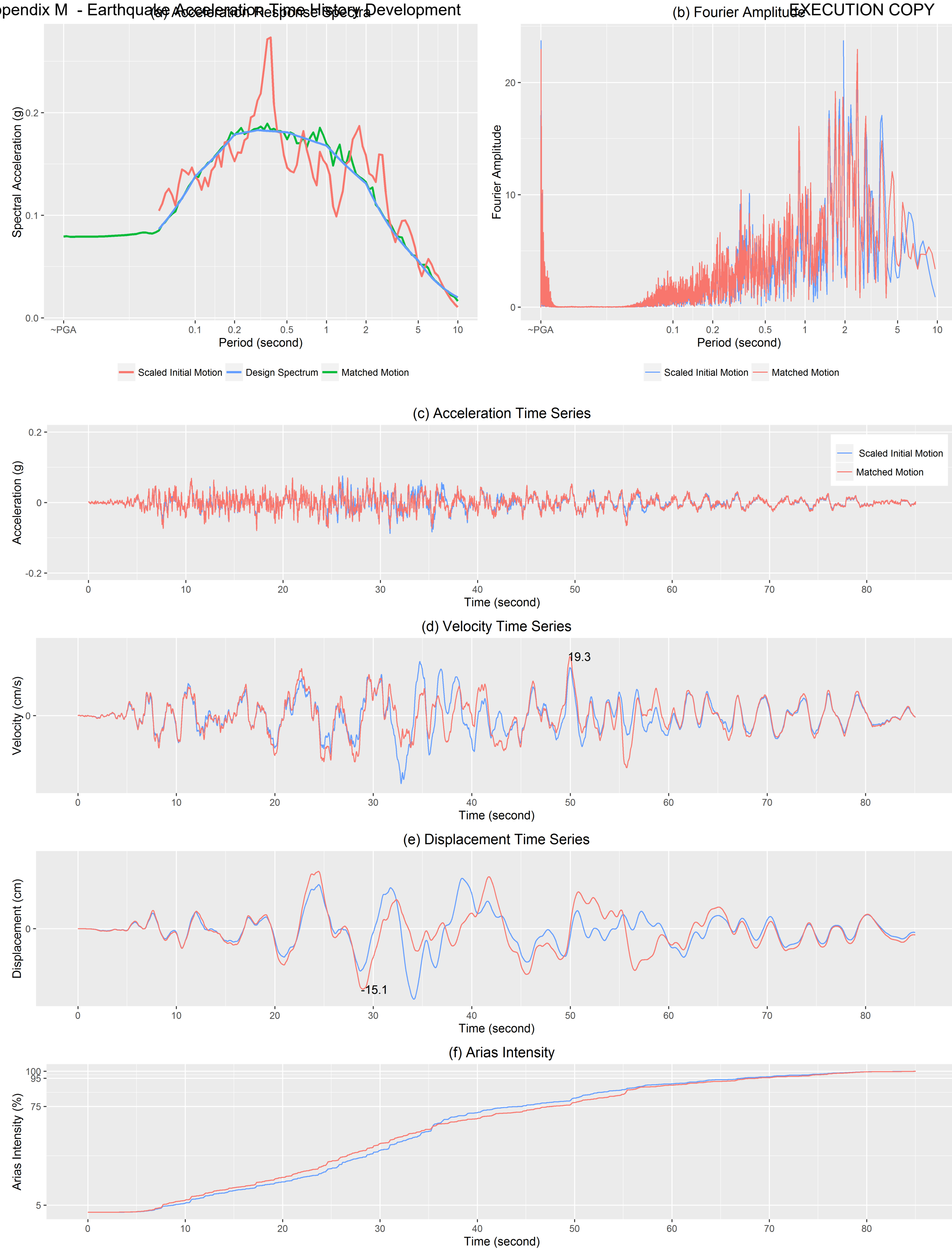
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD105, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A115

2018-11-27 16:31:53 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

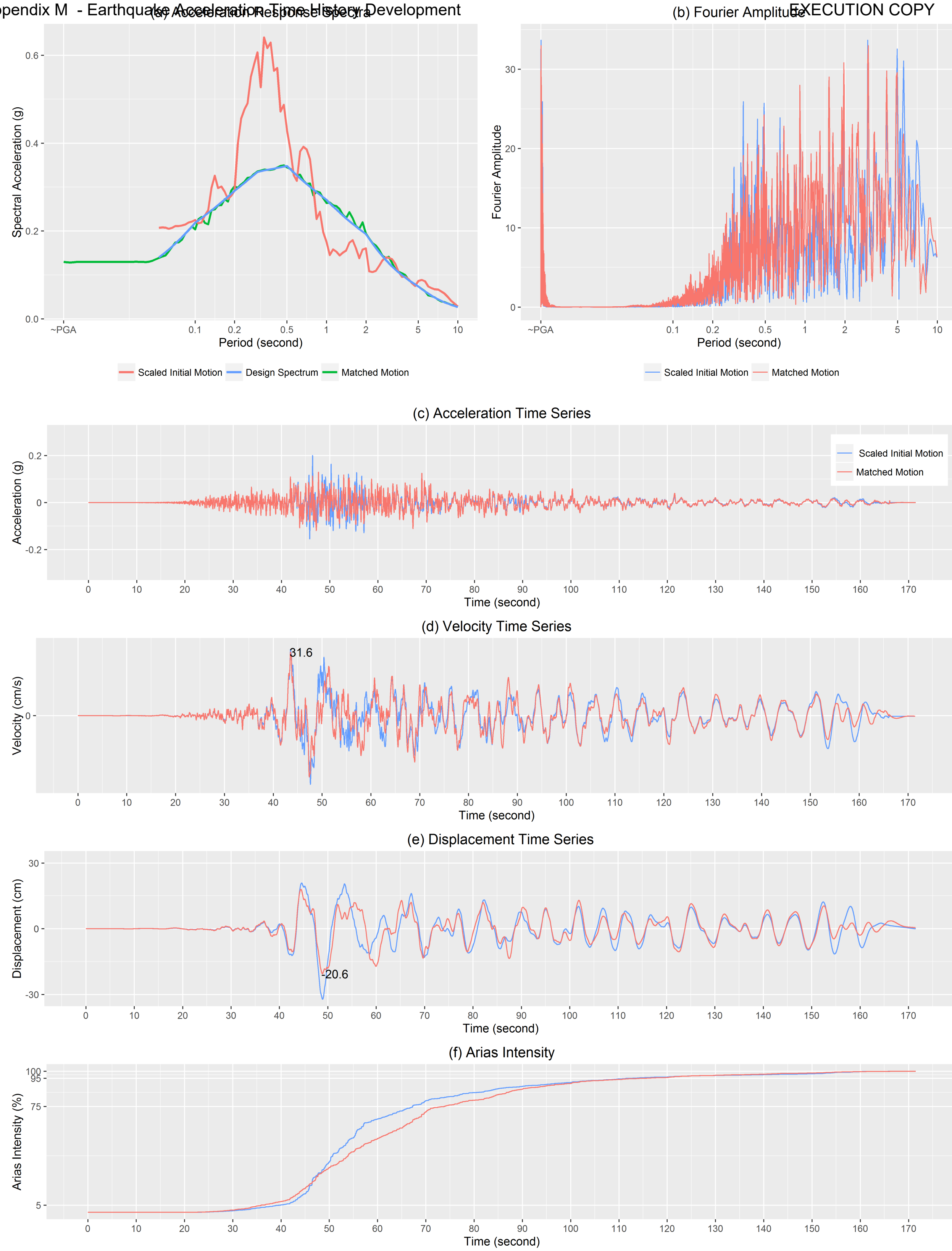
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD105, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A116

2018−11−27 16:32:01 FLi



CLIENT **STANTEC CONSULTANTS INC.**	PROJECT **ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

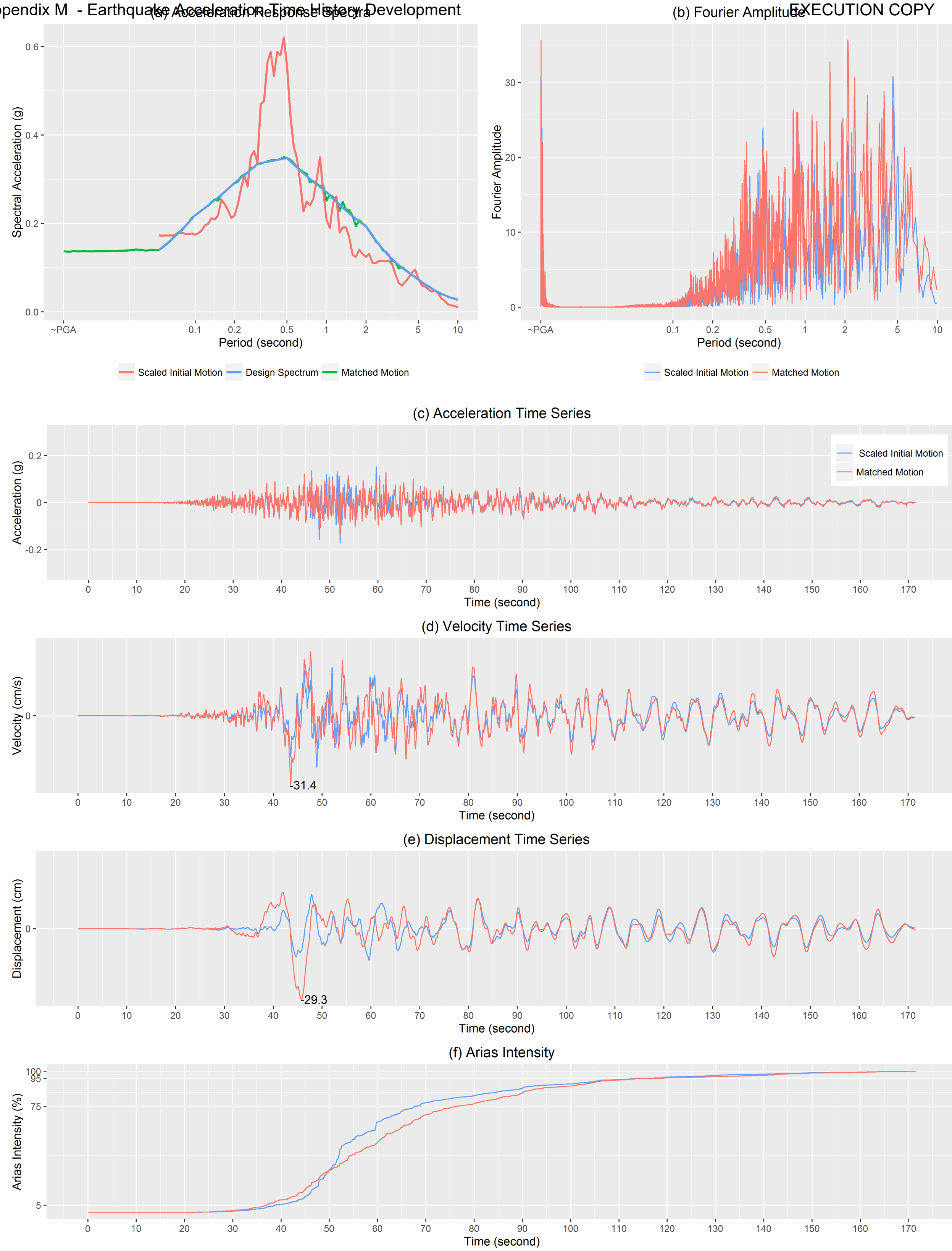
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD181, EW)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A117

2018-11-27 16:32:09 FLI



CLIENT	PROJECT
STANTEC CONSULTANTS INC.	**ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT**

CONSULTANT

GOLDER

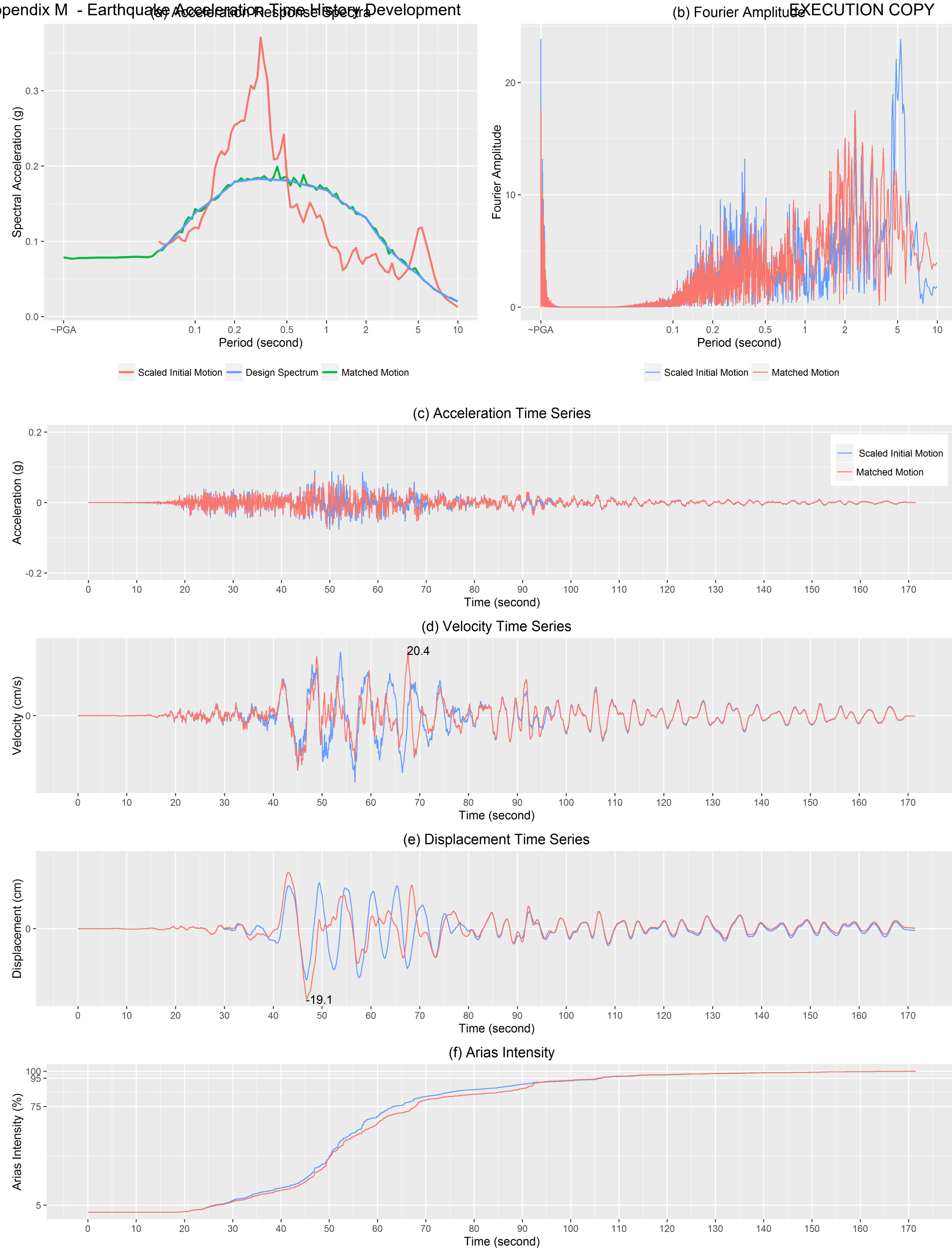
DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD181, NS)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A118

2018−11−27 16:32:17 FLi



CLIENT

STANTEC CONSULTANTS INC.

PROJECT

ACCELERATION TIME HISTORY DEVELOPMENT FOR BROADWAY SUBWAY PROJECT

CONSULTANT

GOLDER

DD/MM/YYYY	11/27/2018
PREPARED	AR
DESIGN	AR
REVIEW	FL
APPROVED	AH

TITLE

SPECTRAL MATCHING RESULTS FOR 2475−YEAR RETURN PERIOD TOKACHIOKI, JAPAN (2003, HKD181, UD)

PROJECT No.	PHASE	REV.	FIGURE
1419105	7100	A	A119

2018-11-27 16:32:25 FLI

APPENDIX B

Important Information and Limitations of This Report

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist.

In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

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