APPENDIX C: EPI Sensitivity Analysis Results

This appendix section contains the following materials:

- Sensitivity analysis results of k_v, GWL, and ground motion intensity parameters as presented in Chapter 5.
- Typical ESA results of adjacent sites with contrast soil layer stratification.

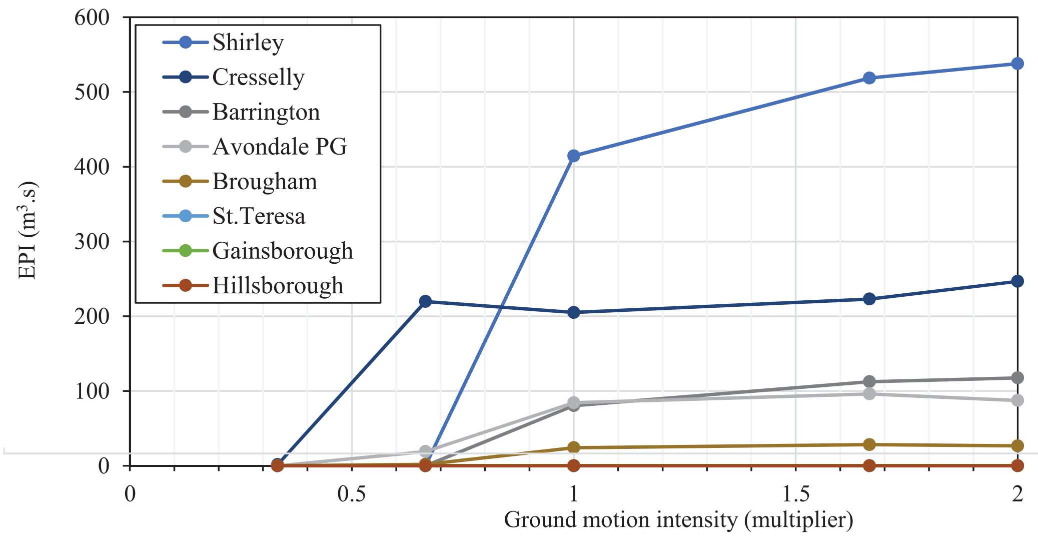


Figure C-1. Computed EPI values with different ground motion intensity level for sites with different manifestation orderly plotted from extreme (top) to none (bottom).

Findings:

1. EPI values for sites without ejecta manifestation (e.g., Gainsborough and St. Teresa) are always zero for different shaking intensity levels. The significant kv contrast of the highly-stratified deposit prevents the upward seepage-induced secondary liquefaction at a shallow depth to occur, and EPI well captures this process. EPI can distinguish sites with and without ejecta effectively as it can capture the post-shaking upward seepage mechanism. The changes of GWL, kv, and input motion PGA do not influence the computed EPI, which confirms that the layer stratification is the main reason why ejecta was not produced at these two sites.

2. The computed EPI values for sites with more ejecta manifestation tends to reach a convergence value at more vigorous shaking intensity. The liquefiable deposit has a maximum amount of residual excess pore water pressure generated during shaking, and the thickness of the liquefied layer of a site has a maximum value. Hence, EPI is consistent in capturing this mechanism. Different intensity may change the thickness of the liquefied layer during shaking and change when and where the first liquefaction occurs.

3. As expected, the shaking intensity is sensitive to the computed EPI values only during shaking and relatively minor after the shaking stop. The post-shaking AFP time history tends to have a similar dissipation shape and reach a similar value as soil hydraulic conductivity is the controlling parameter during the advection stage.

4. More vigorous intensity does not necessarily increase the computed EPI value significantly as it can cause more severe deep liquefaction that may reduce the seismic demand for shallow soils. This mechanism is also captured by computed EPI values, as indicated in Figure D-1.

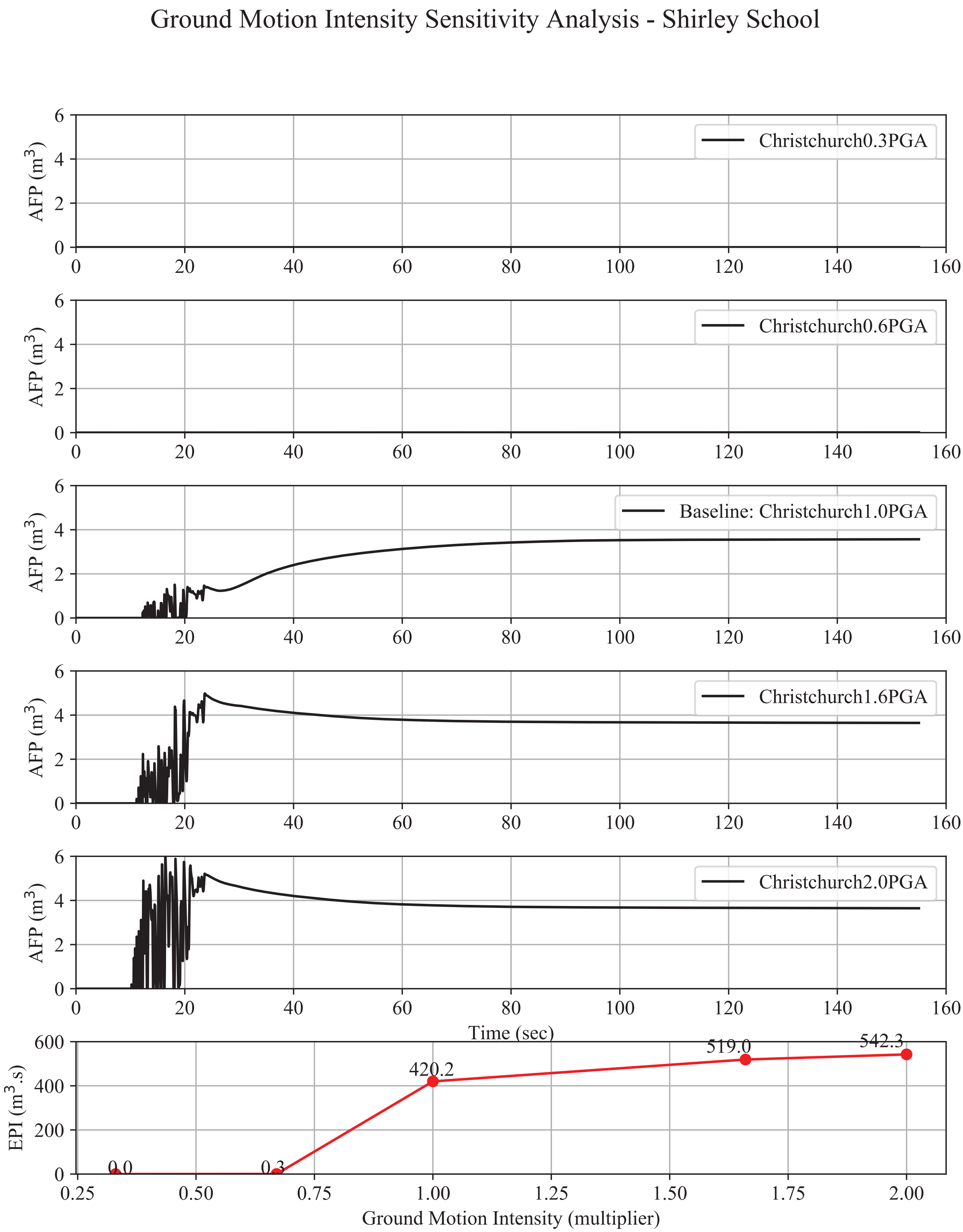


Figure C-2. Variation of AFP and EPI values of Shirley School due to varying PGA intensity level

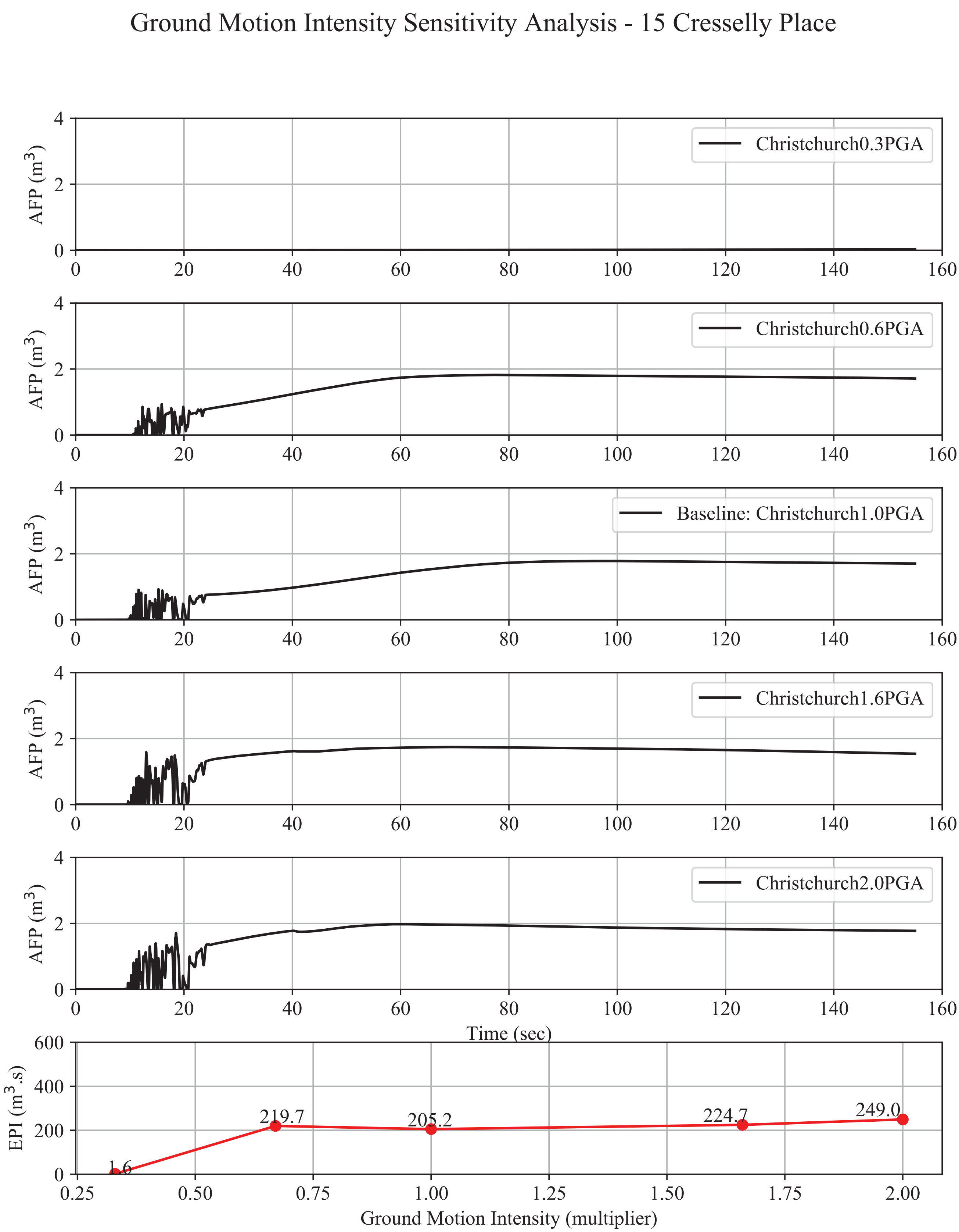


Figure C-3. Variation of AFP and EPI values of Cresselly Place due to varying PGA intensity level

Ground Motion Intensity Sensitivity Analysis - Avondale Playground

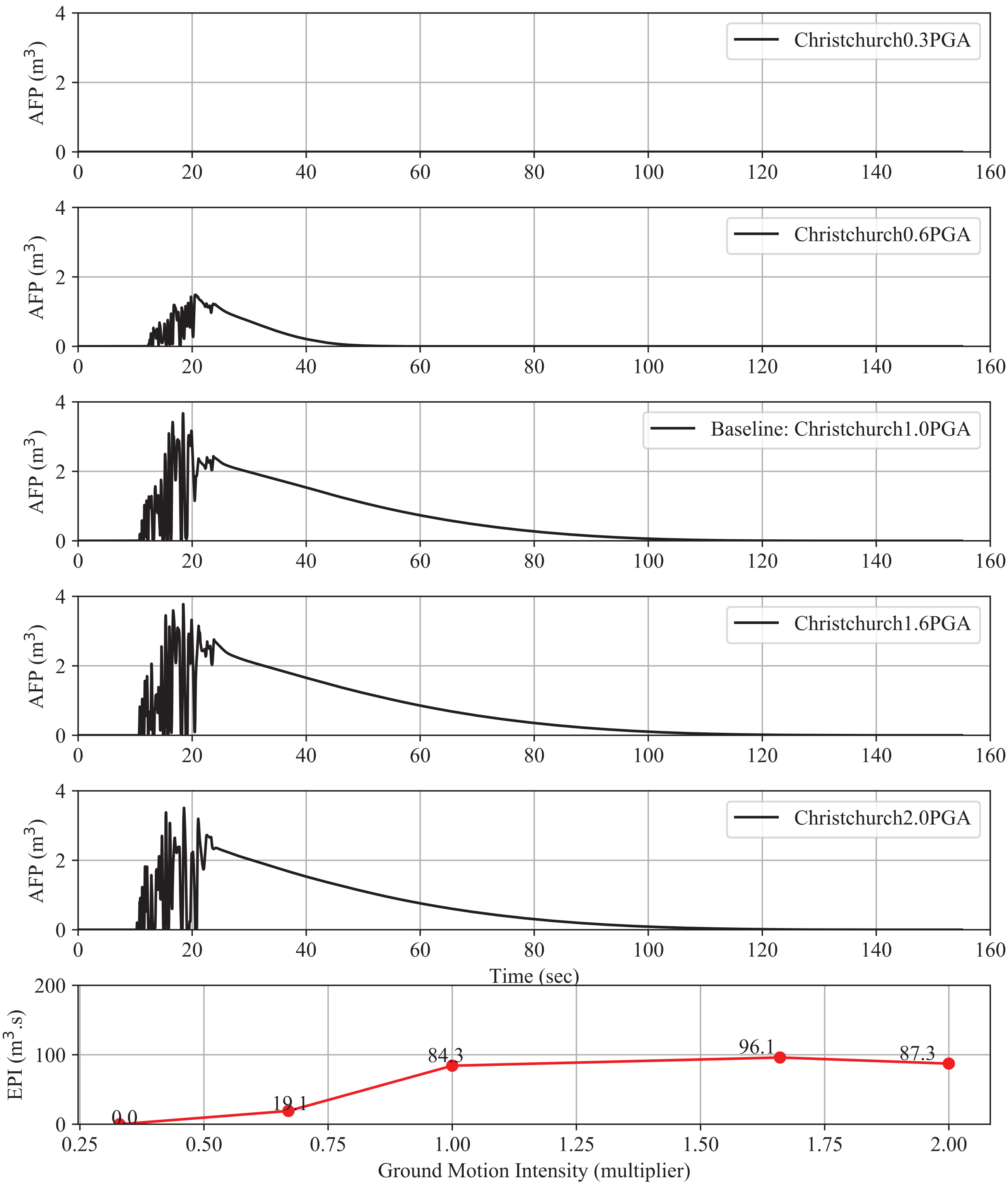


Figure C-4. Variation of AFP and EPI values of Avondale PG due to varying PGA intensity level

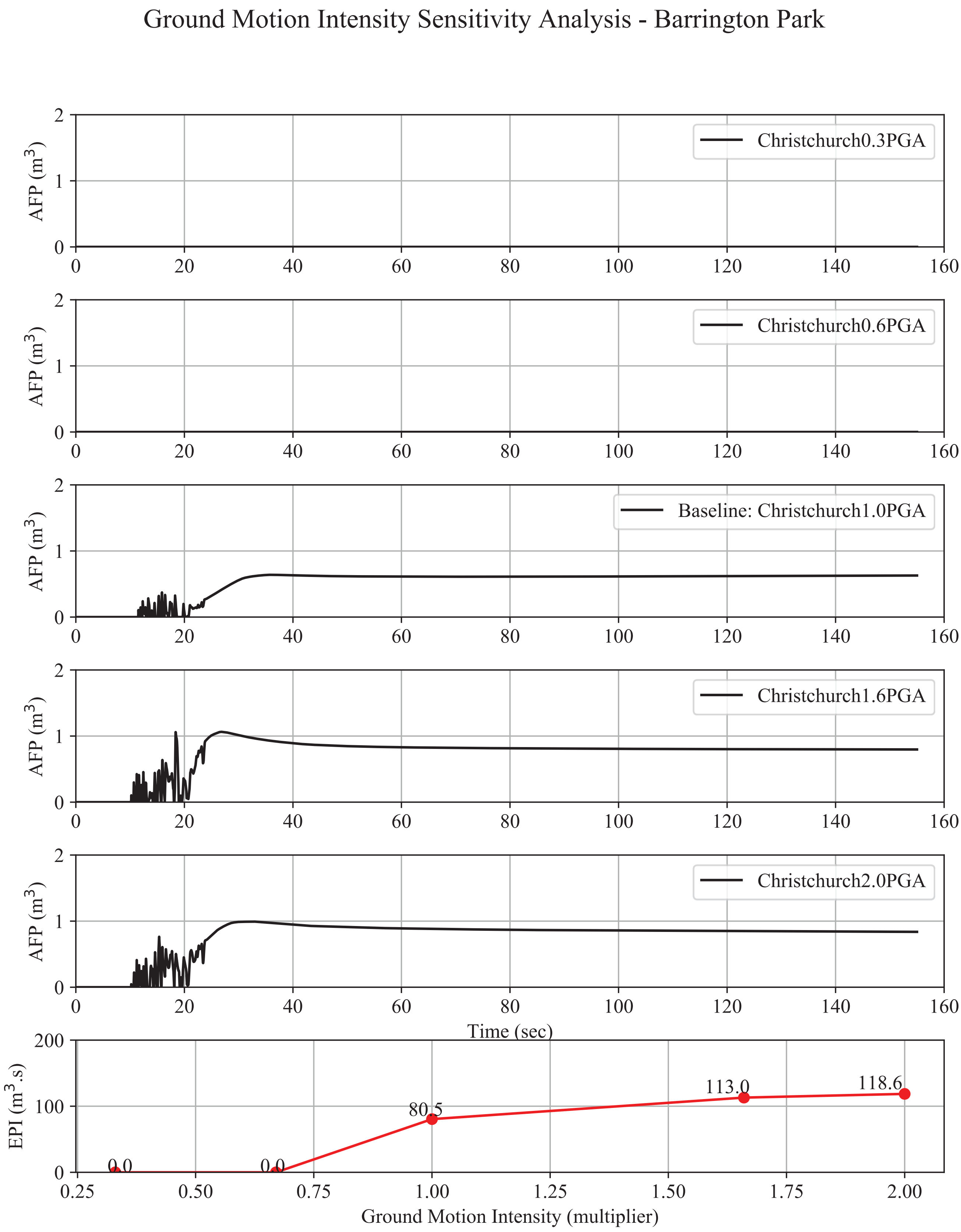


Figure C-5. Variation of AFP and EPI values of Barrington Park due to varying PGA intensity level

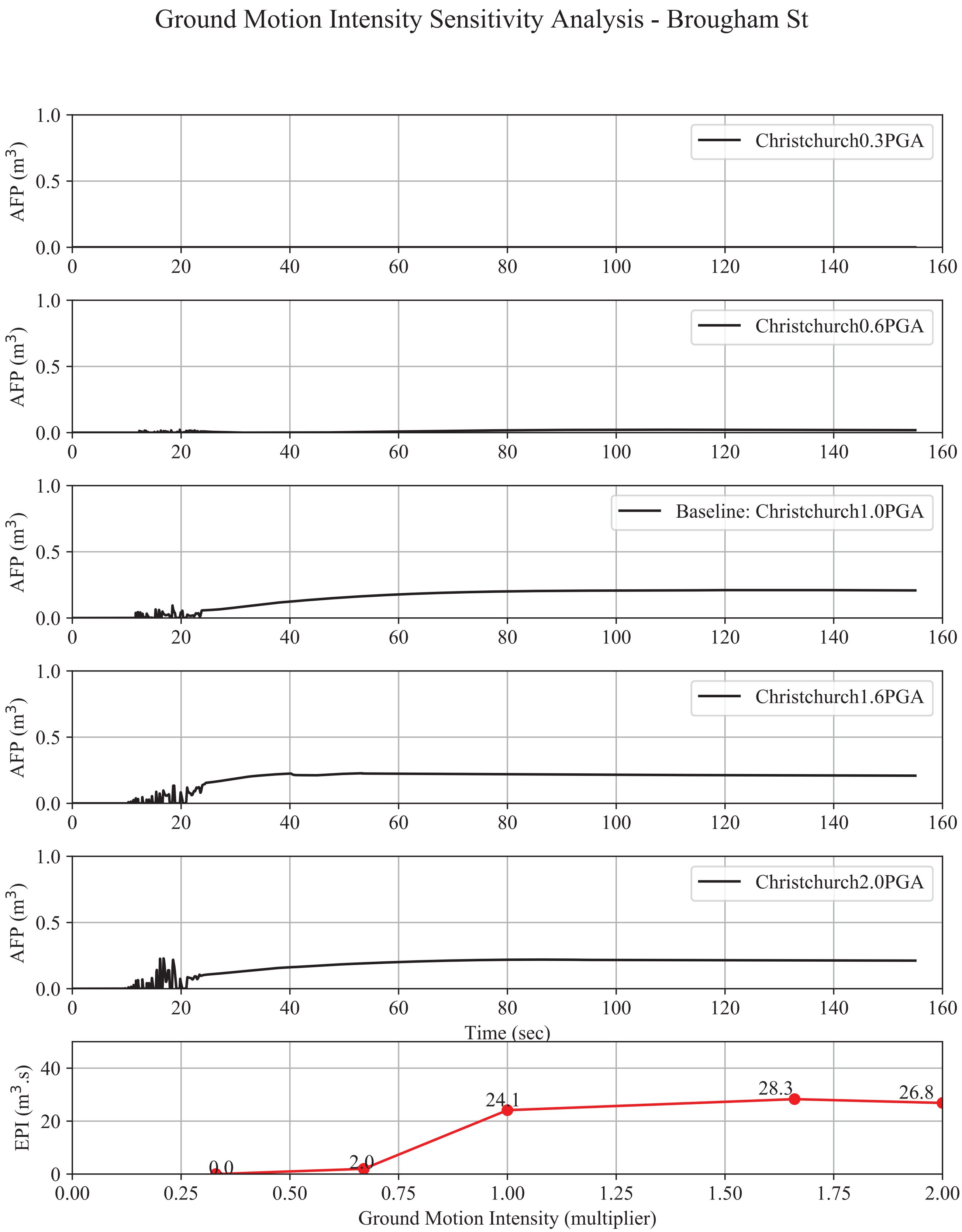


Figure C-6. Variation of AFP and EPI values of Brougham St. due to varying PGA intensity level

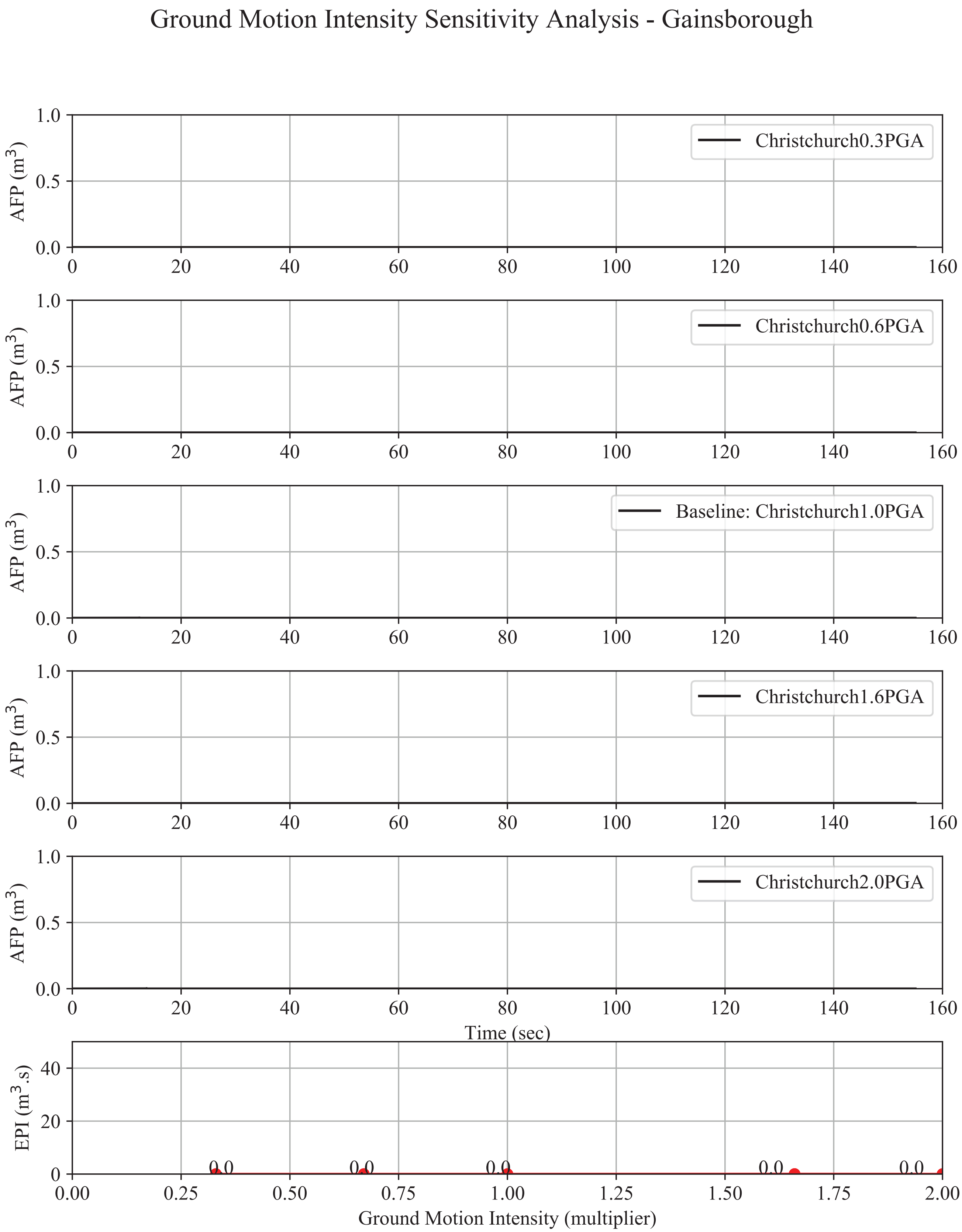


Figure C-7. Variation of AFP and EPI values of Gainsborough Res. due to varying PGA intensity level

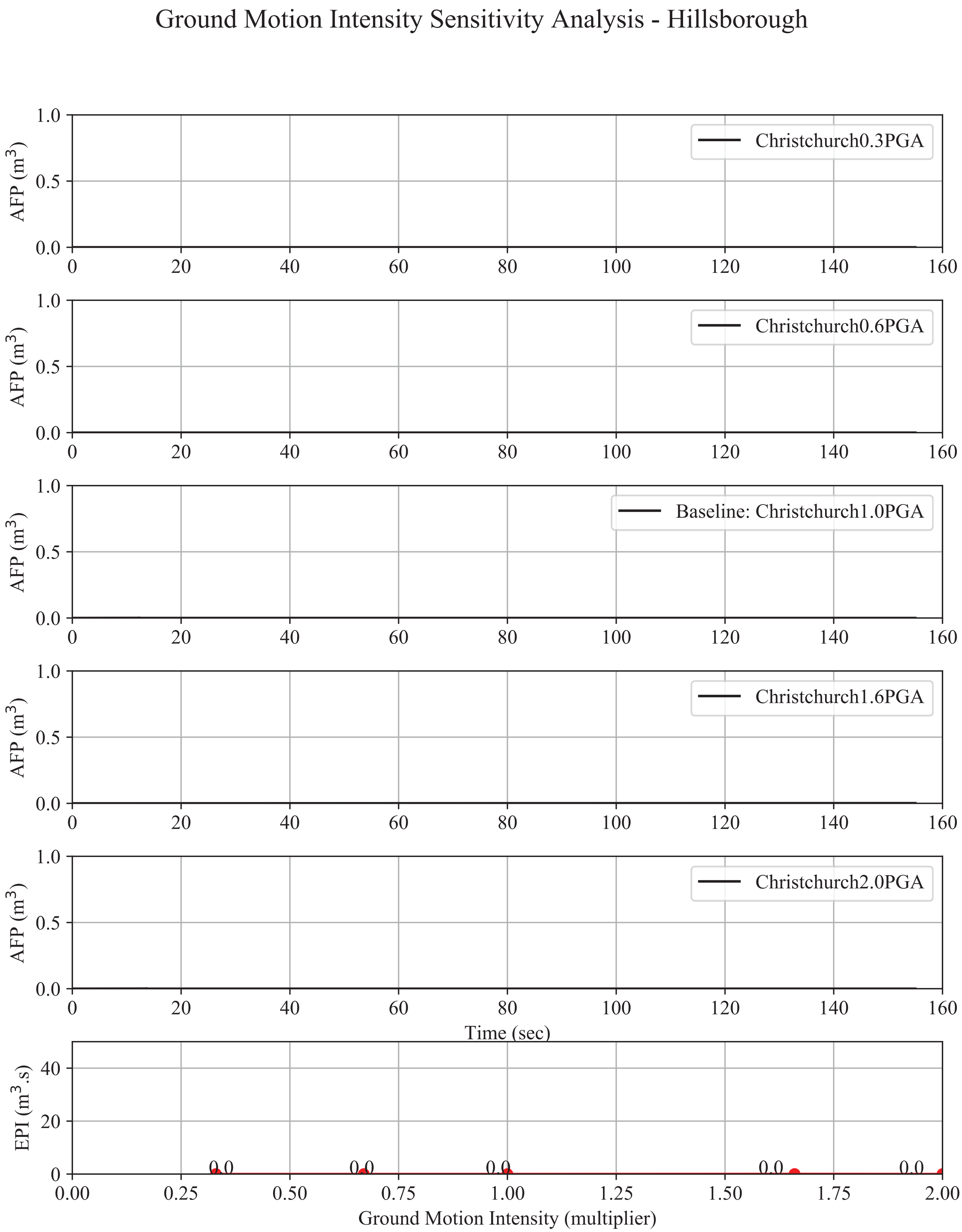


Figure C-8. Variation of AFP and EPI values of Hillsborough due to varying PGA intensity level

Ground Motion Intensity Sensitivity Analysis - St.Teresa

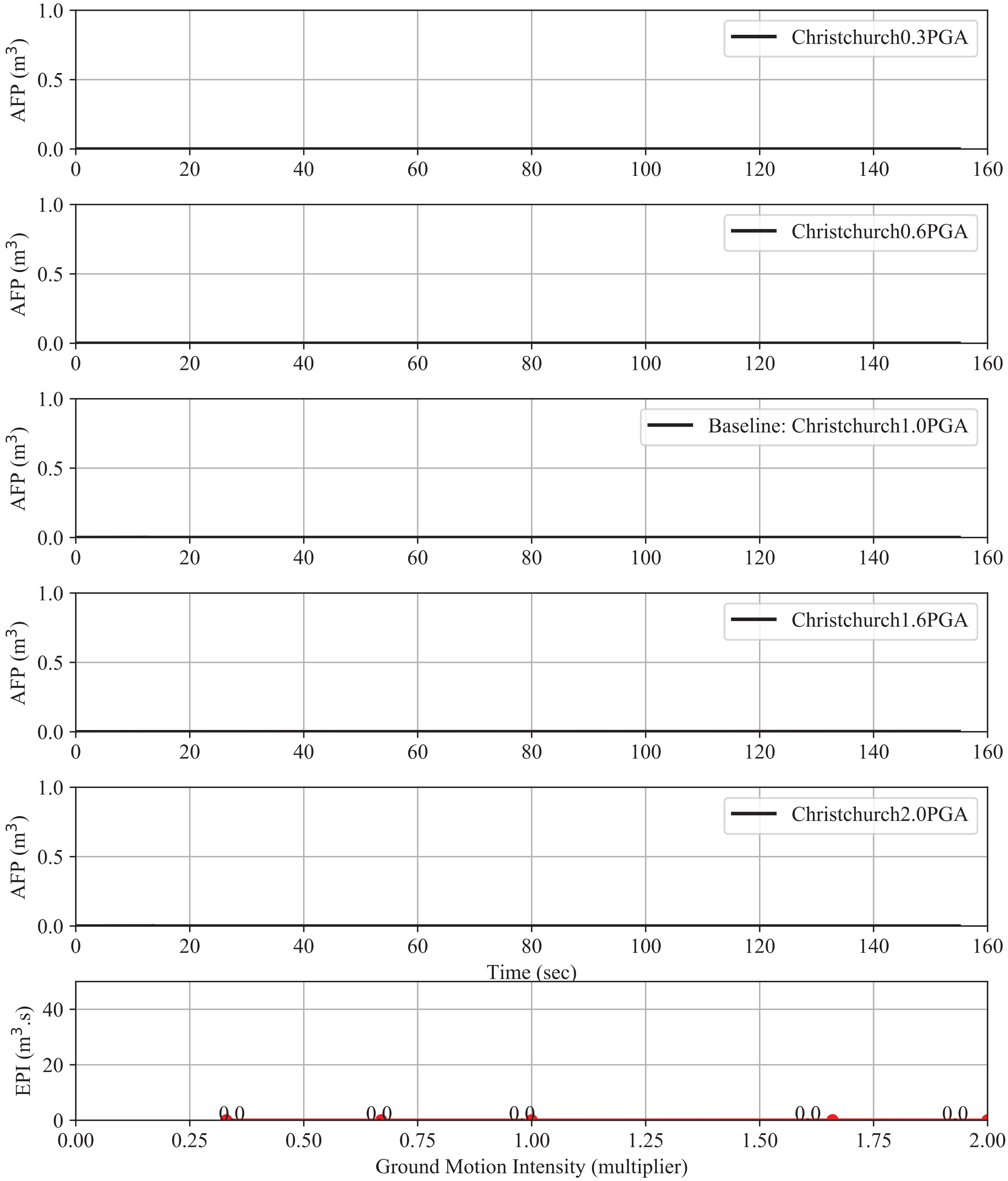


Figure C-9. Variation of AFP and EPI values of St. Teresa due to varying PGA intensity level

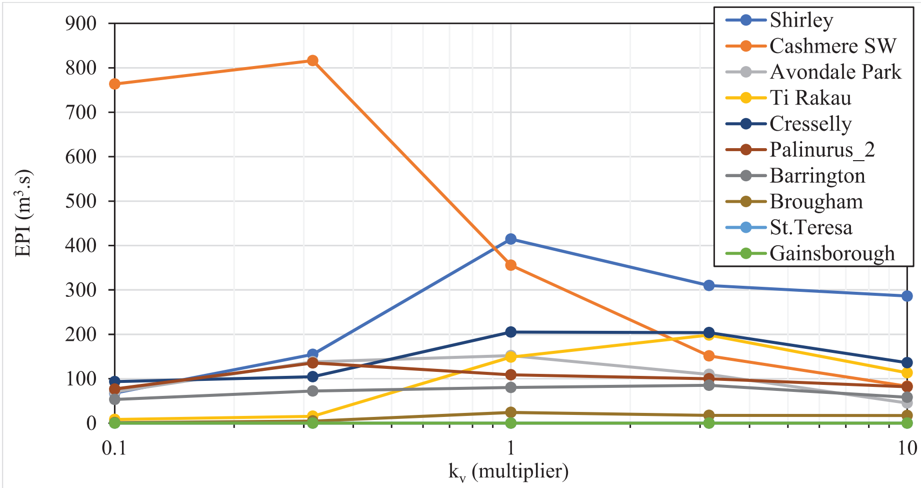


Figure D-10. Computed EPI values with different hydraulic conductivity (k_v) parameters for sites with different manifestation orderly plotted from extreme (top) to none (bottom).

Findings:

1. EPI values for sites without ejecta manifestation (e.g., Gainsborough and St. Teresa) are always zero for different k_v value. The significant kv contrast of the highly-stratified deposit prevents the upward seepage-induced secondary liquefaction at a shallow depth to occur, and EPI well captures this process. EPI can distinguish sites with and without ejecta effectively as it can capture the post-shaking upward seepage mechanism.

2. The computed EPI values for sites with more ejecta manifestation are more sensitive to changes in k_v value. However, EPI for these sites is always greater than zero, consistent with the field observation.

3. The in-situ k_v value is a difficult parameter to obtain, and it can vary within one order of magnitude. The Robertson & Cabal (2015) CPT- kv correlation estimates a reasonable k_v value for typical soil materials and is used as the baseline. The severity criteria of EPI is derived empirically after comparing the computed value to a set of field observation case history. That process requires acceptable baseline assumptions and should be determined to provide a consistent comparison. The estimation trend resulted in this study is based on where Robertson & Cabal (2015) are used to estimate k_v.

4. The variation of EPI during shaking is lower and increases during the advection process. As expected, hydraulic conductivity is not a primary parameter that controls the generation of excess pore pressure during shaking. However, once the shaking stops, the advection process is primarily controlled by hydraulic conductivity.

5. During shaking, k_v influences the dissipation of u_e, where high-k_v soil dissipates the u_e rapidly and prevents liquefaction. Conversely, a low-k_v deposit dissipates the u_e slowly, causing the liquefied state to become easier to reach during a continuous shearing. After shaking, kv influences the dissipation of u_e of the whole system profile where, on the other hand, high-k_v soil triggers a more intense upward seepage resulting in secondary liquefaction at shallow critical depth. Conversely, low-k_v prevents secondary liquefaction as the intensity of the seepage is lower. In conclusion, as k_v value balances the consequence during and after shaking, when both conditions are met simultaneously, a system profile will have a peak EPI value at a right k_v value, as shown in this sensitivity study.

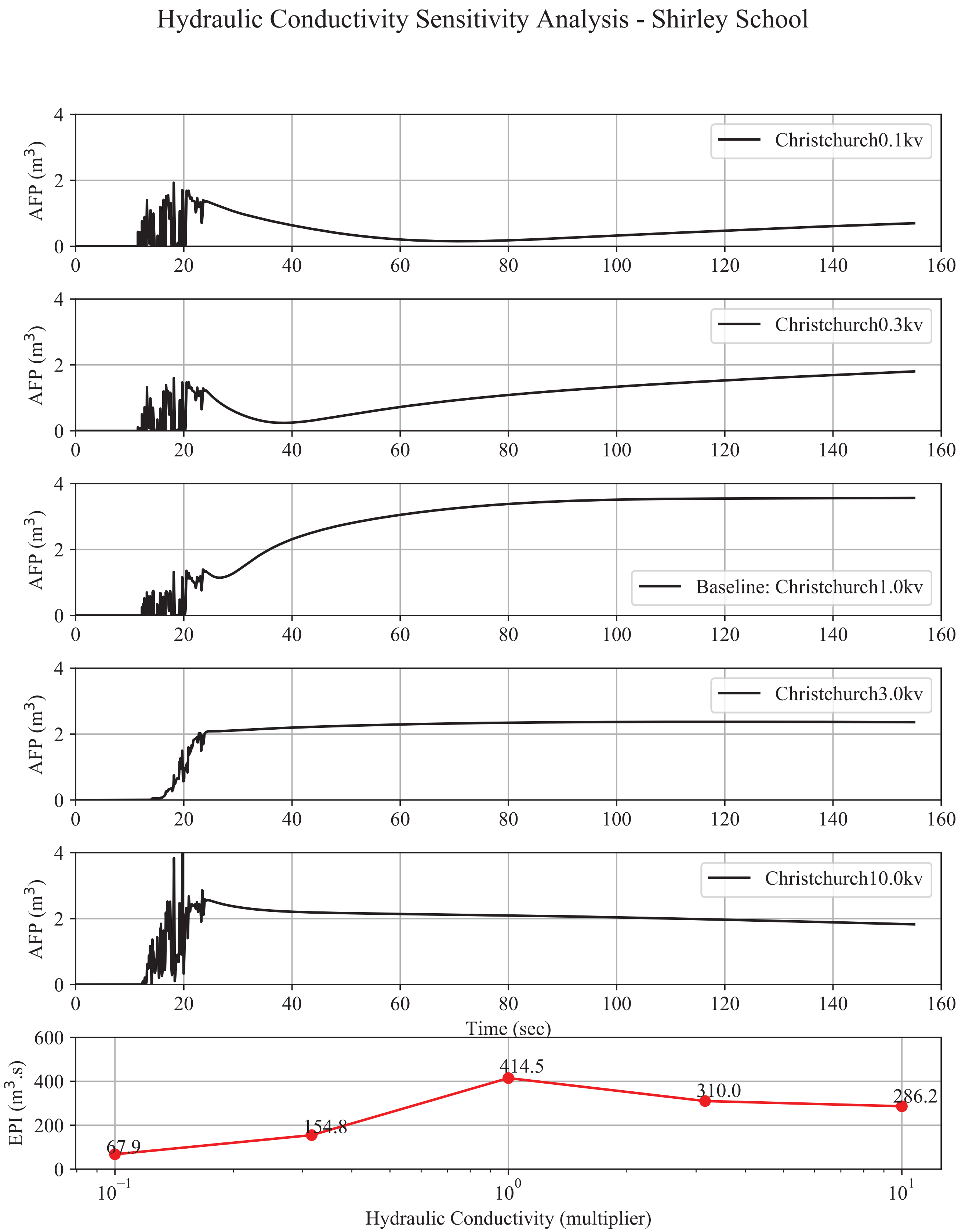


Figure C-11. Variation of AFP and EPI values of Shirley School due to varying k_v value

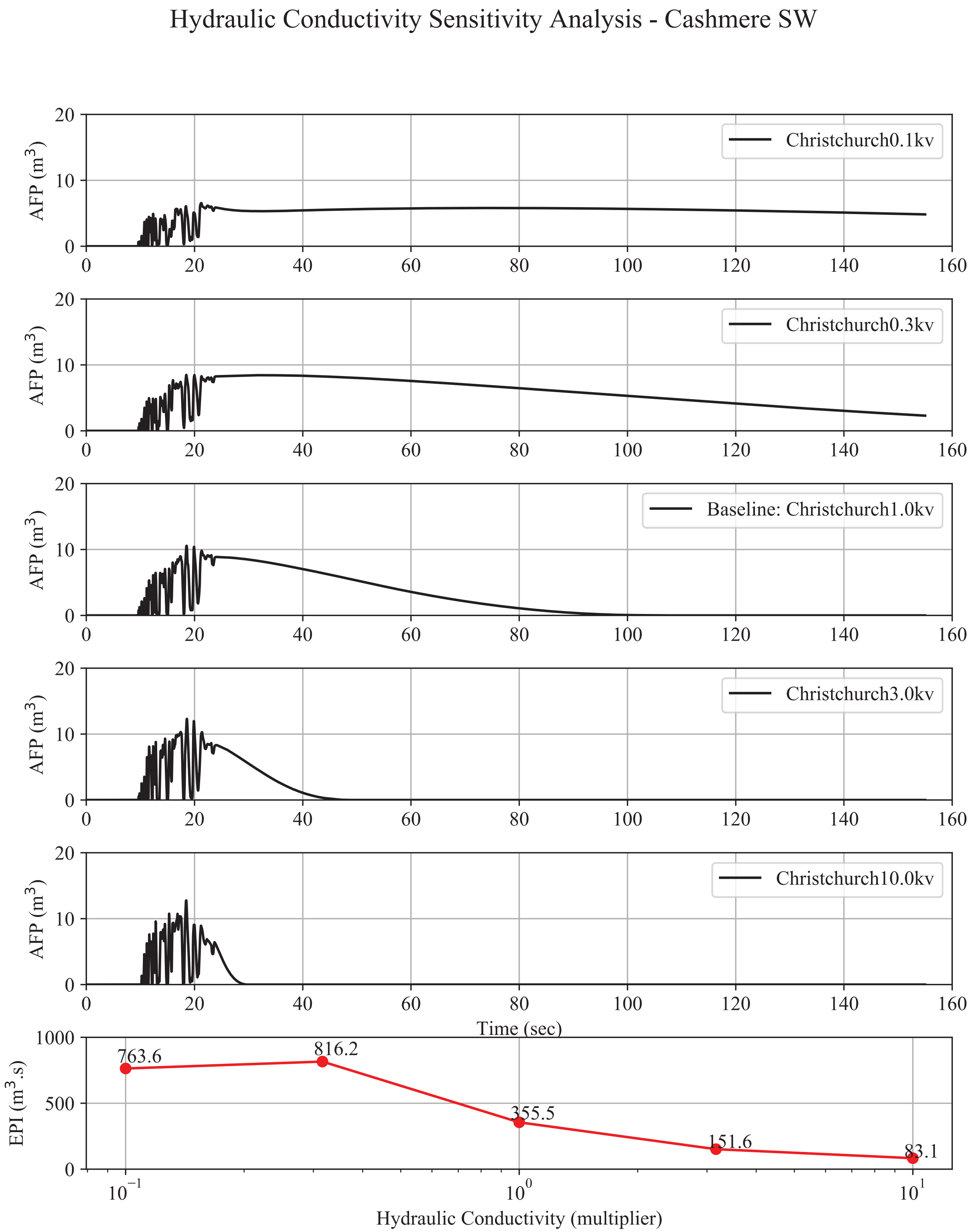


Figure C-12. Variation of AFP and EPI values of Cashmere SW due to varying k_v value

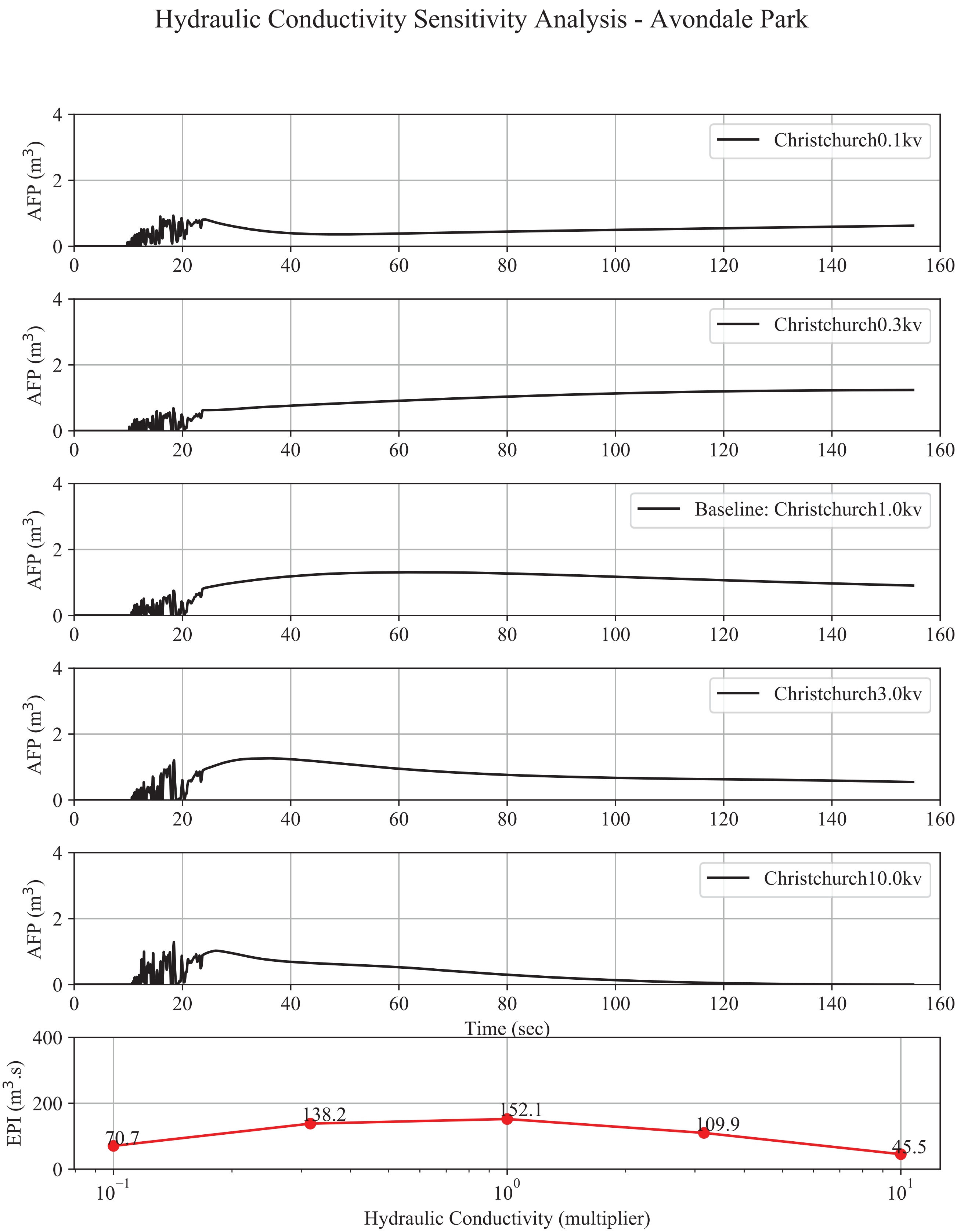


Figure C-13. Variation of AFP and EPI values of Avondale Park due to varying k_v value

Hydraulic Conductivity Sensitivity Analysis - Ti Rakau Reserve

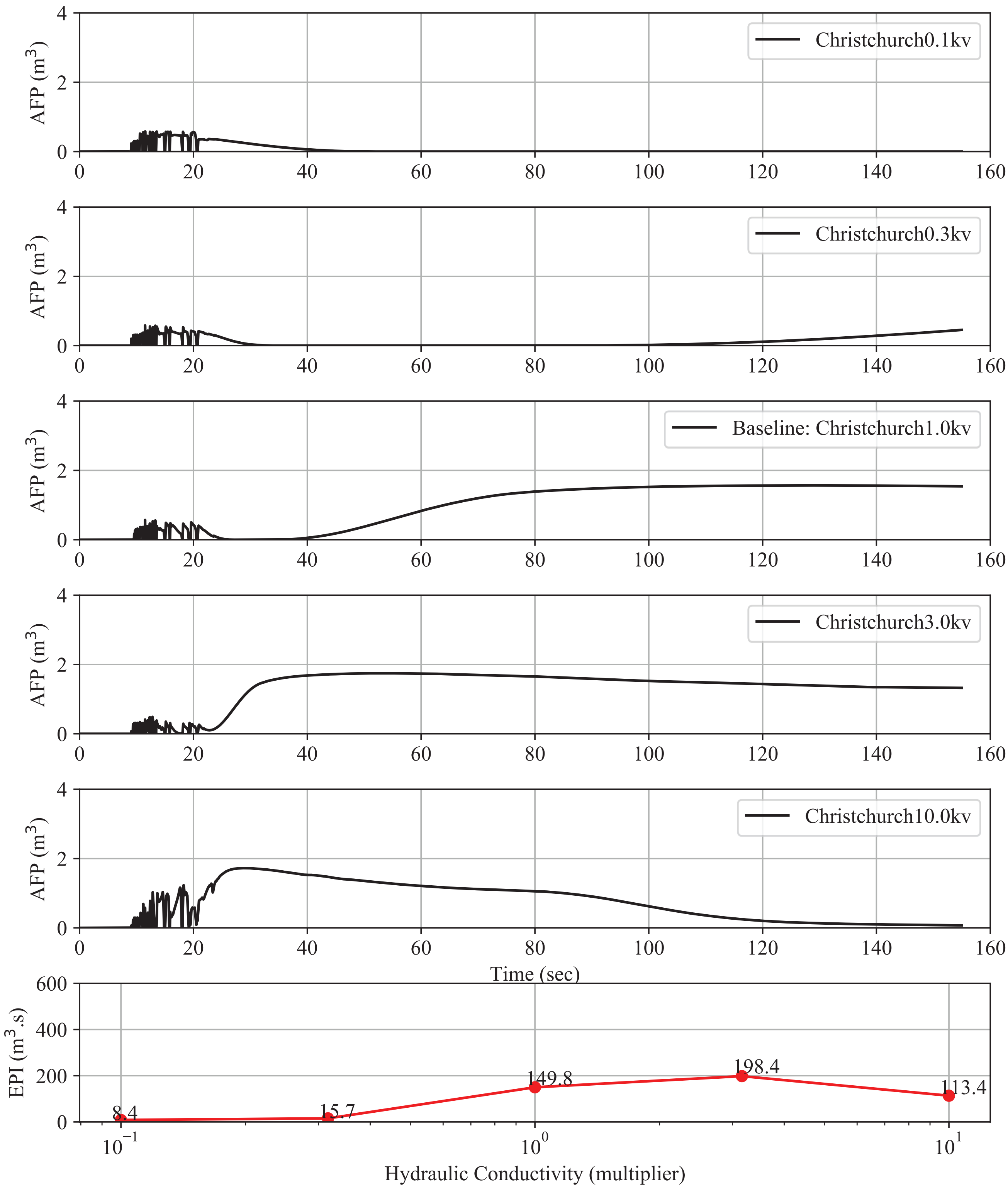


Figure C-14. Variation of AFP and EPI values of Ti Rakau Reserve due to varying k_v value

Hydraulic Conductivity Sensitivity Analysis - 15 Cresselly Place

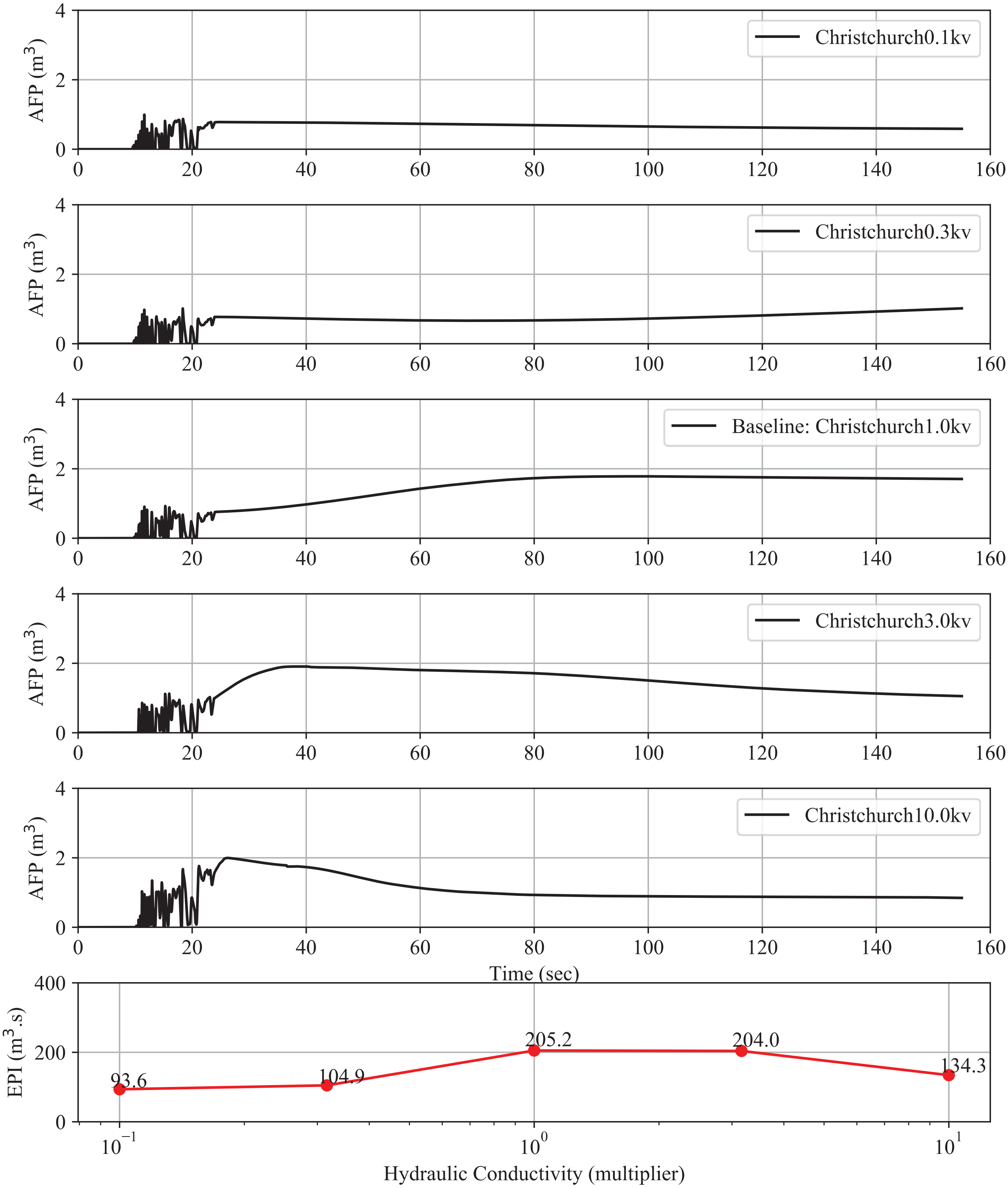


Figure D-15. Variation of AFP and EPI values of Cresselly Place due to varying k_v value

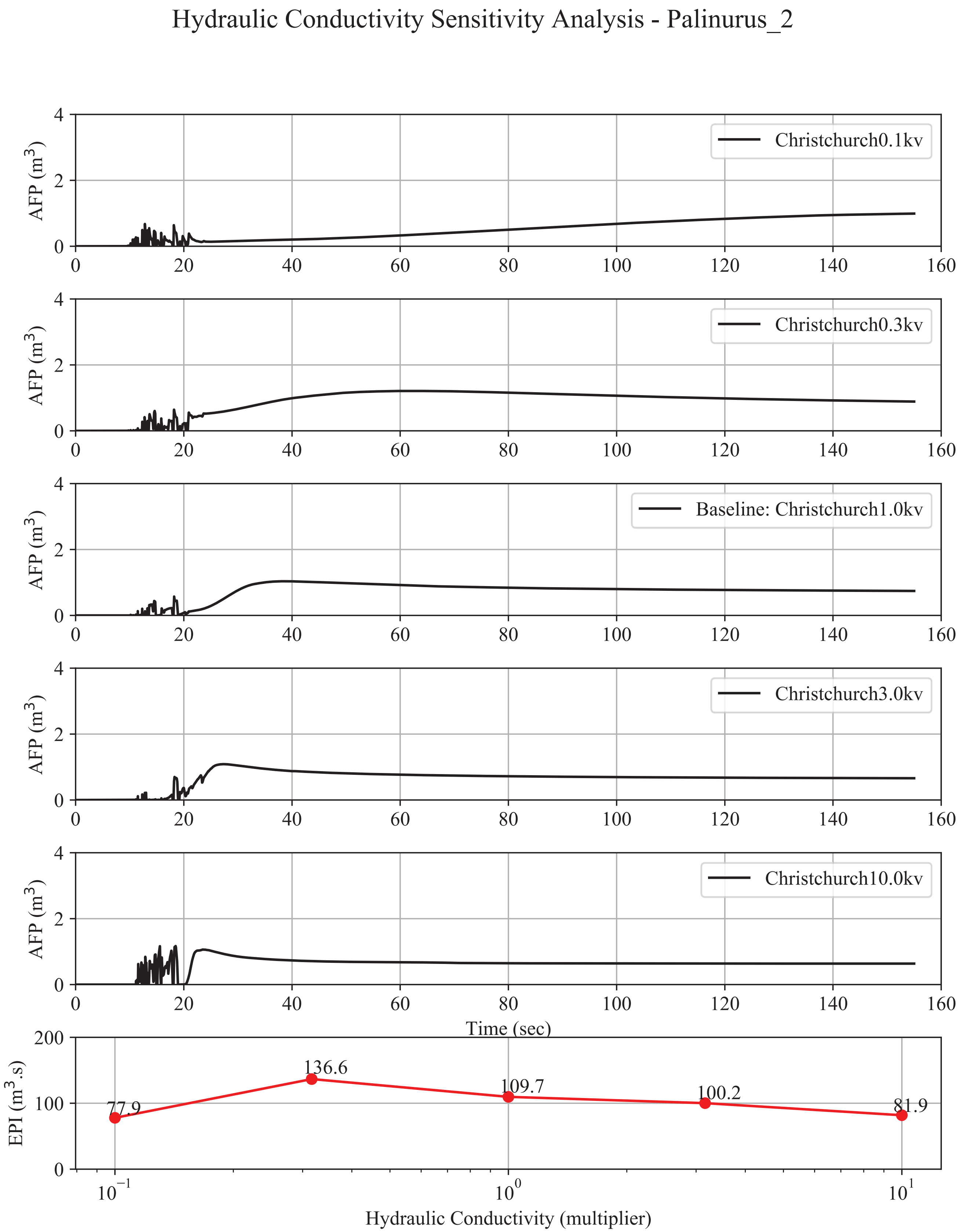


Figure C-16. Variation of AFP and EPI values of Palinurus-2 due to varying k_v value

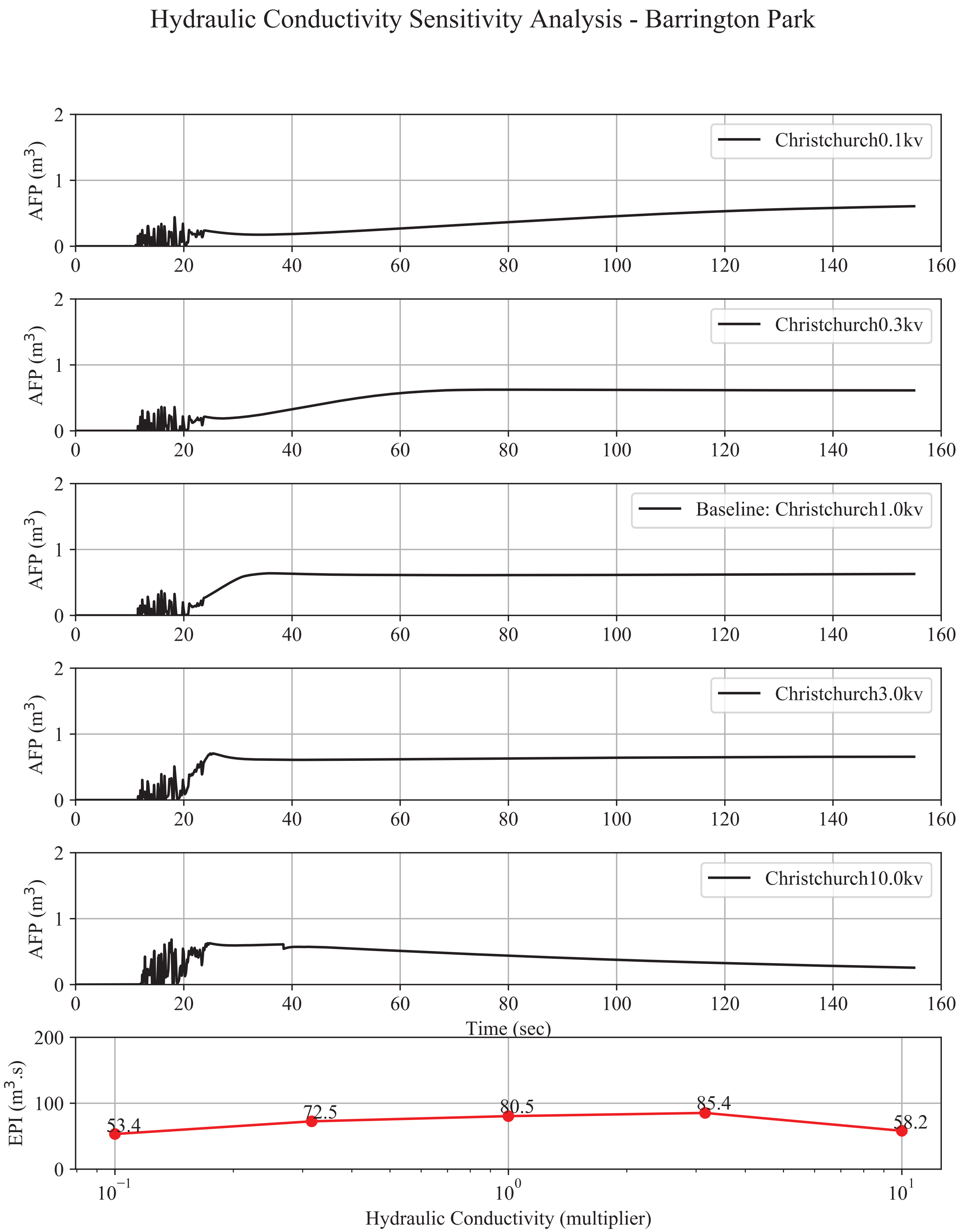


Figure C-17. Variation of AFP and EPI values of Barrington Park due to varying k_v value

Hydraulic Conductivity Sensitivity Analysis - Brougham St

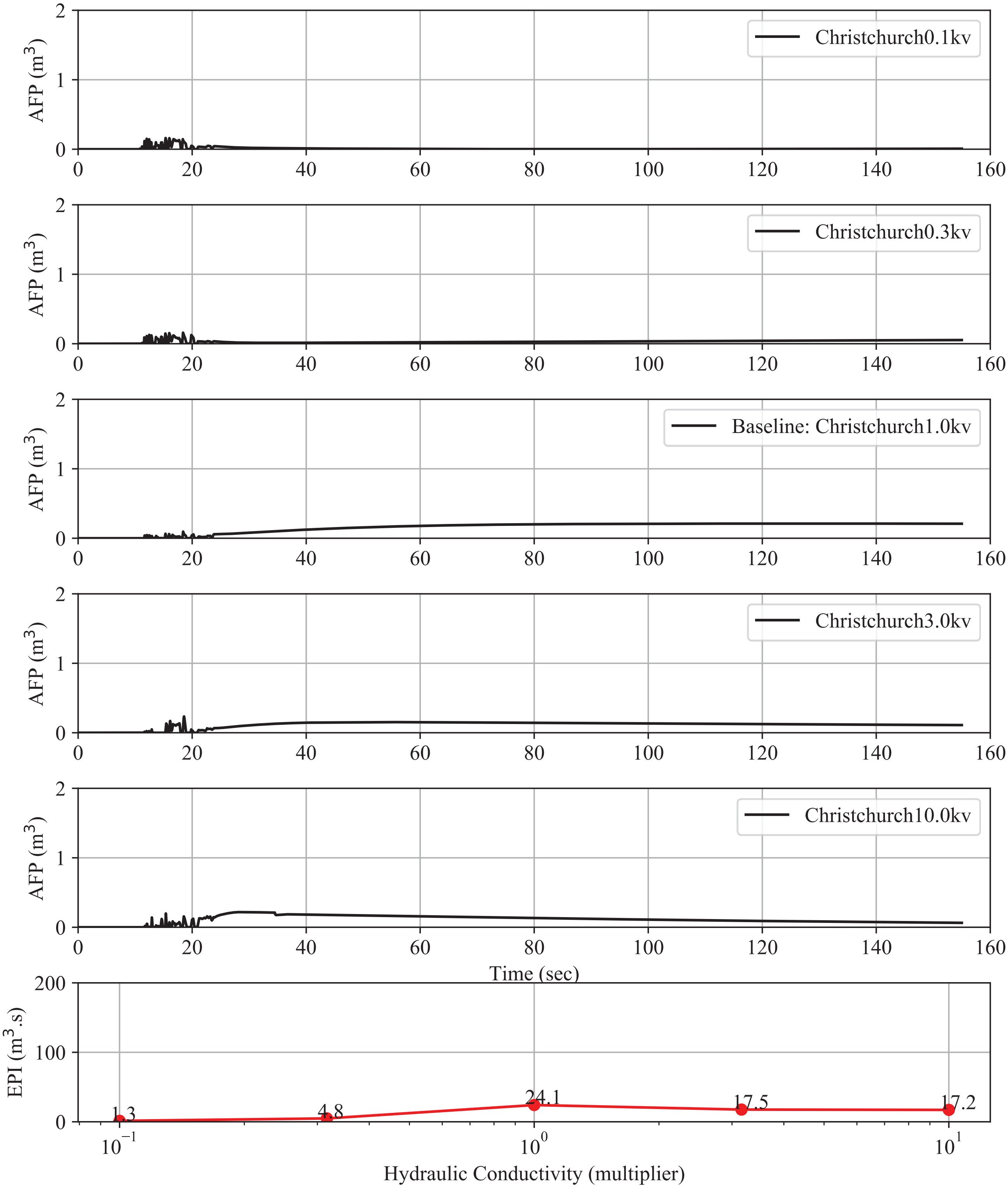


Figure C-18. Variation of AFP and EPI values of Brougham St. due to varying k_v value

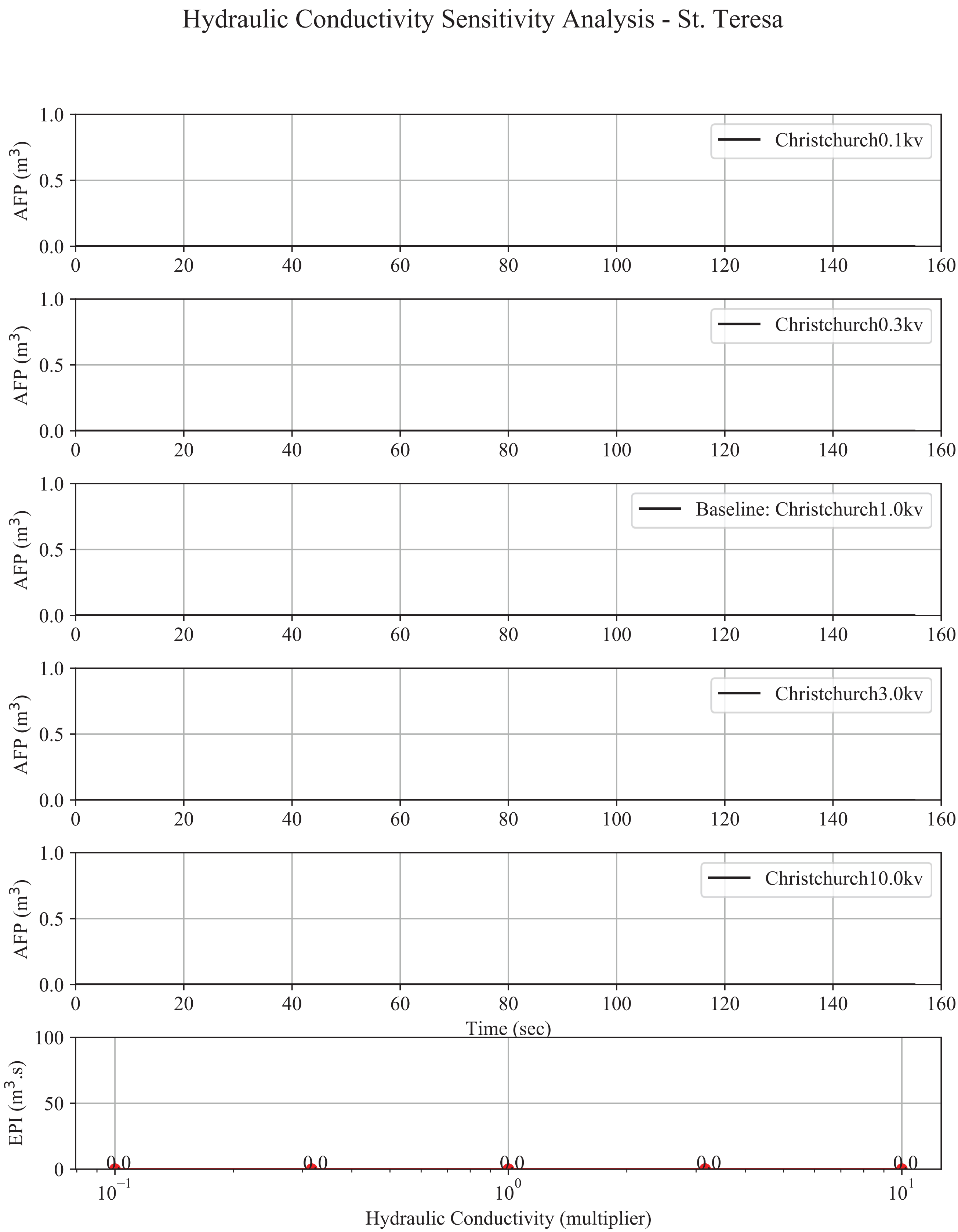


Figure C-19. Variation of AFP and EPI values of St. Teresa due to varying k_v value

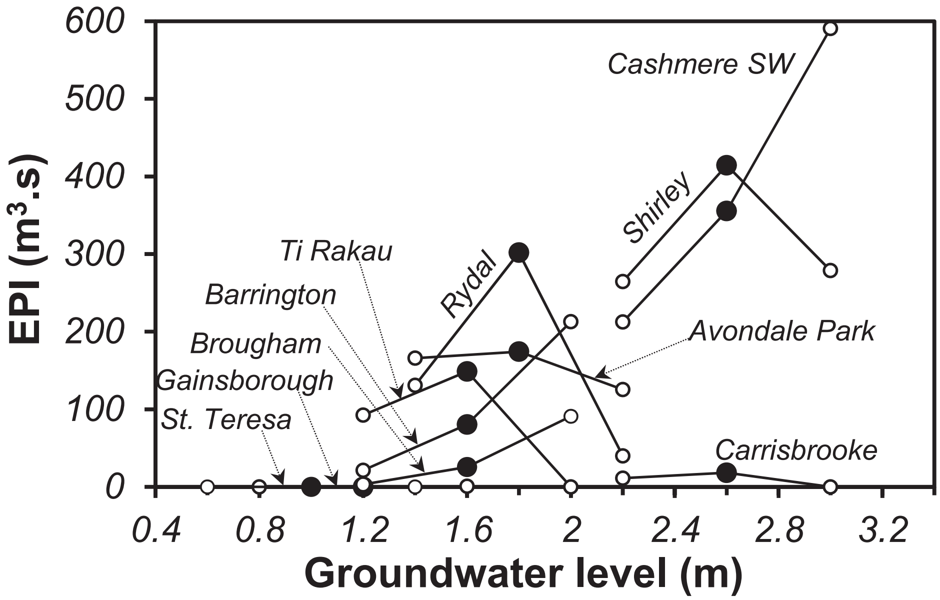


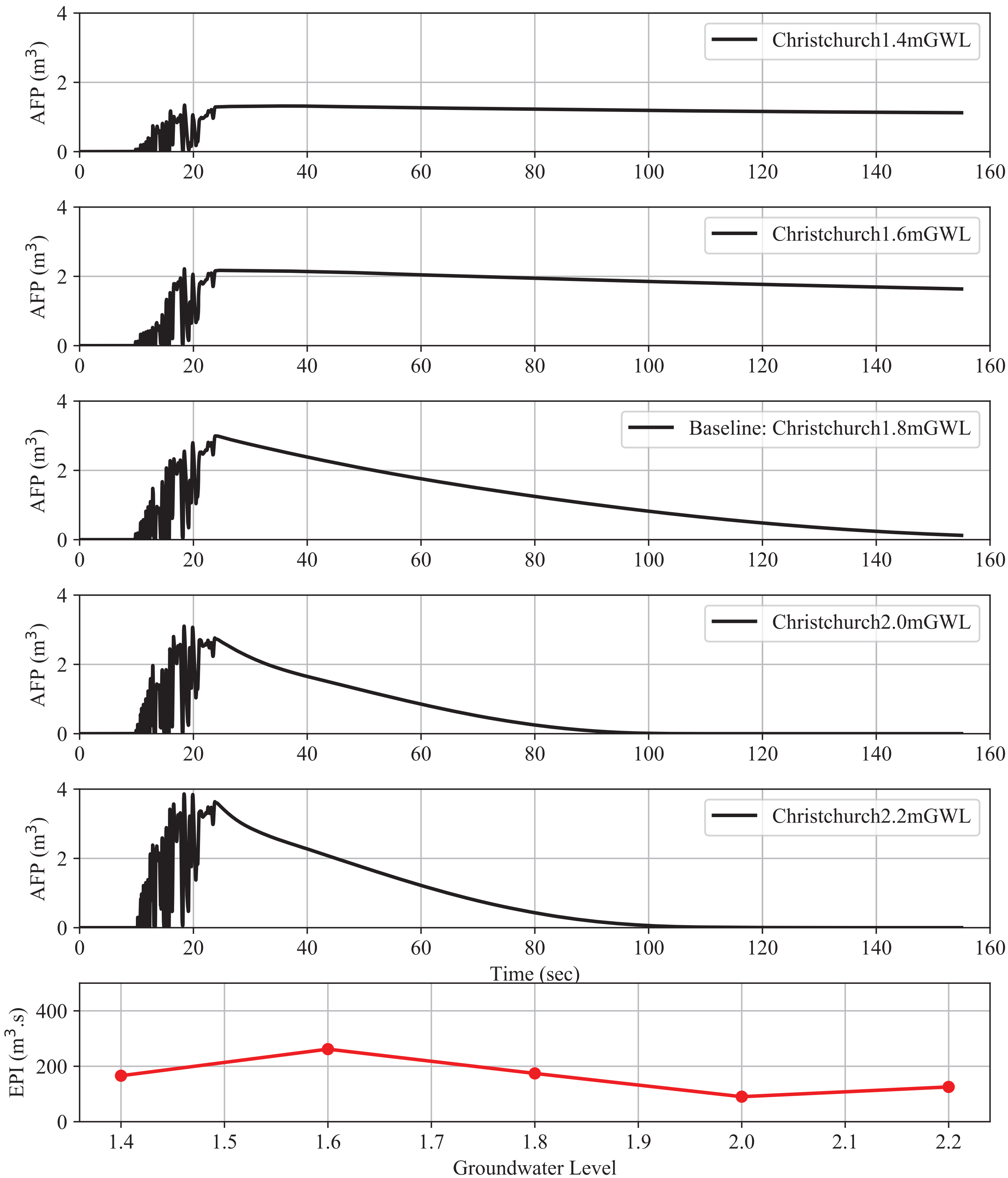
Figure C20. Influence of GWL changes on computed EPI values for 10 level ground sites. Each severity criteria is represented by 2 sites.

None:	St. Teresa & Gainsborough
Minor:	Carisbrooke & Brougham Street
Moderate:	Barrington & Avondale
Severe:	Rydal & Ti Rakau Reserve
Extreme:	Cashmere SW & Shirley

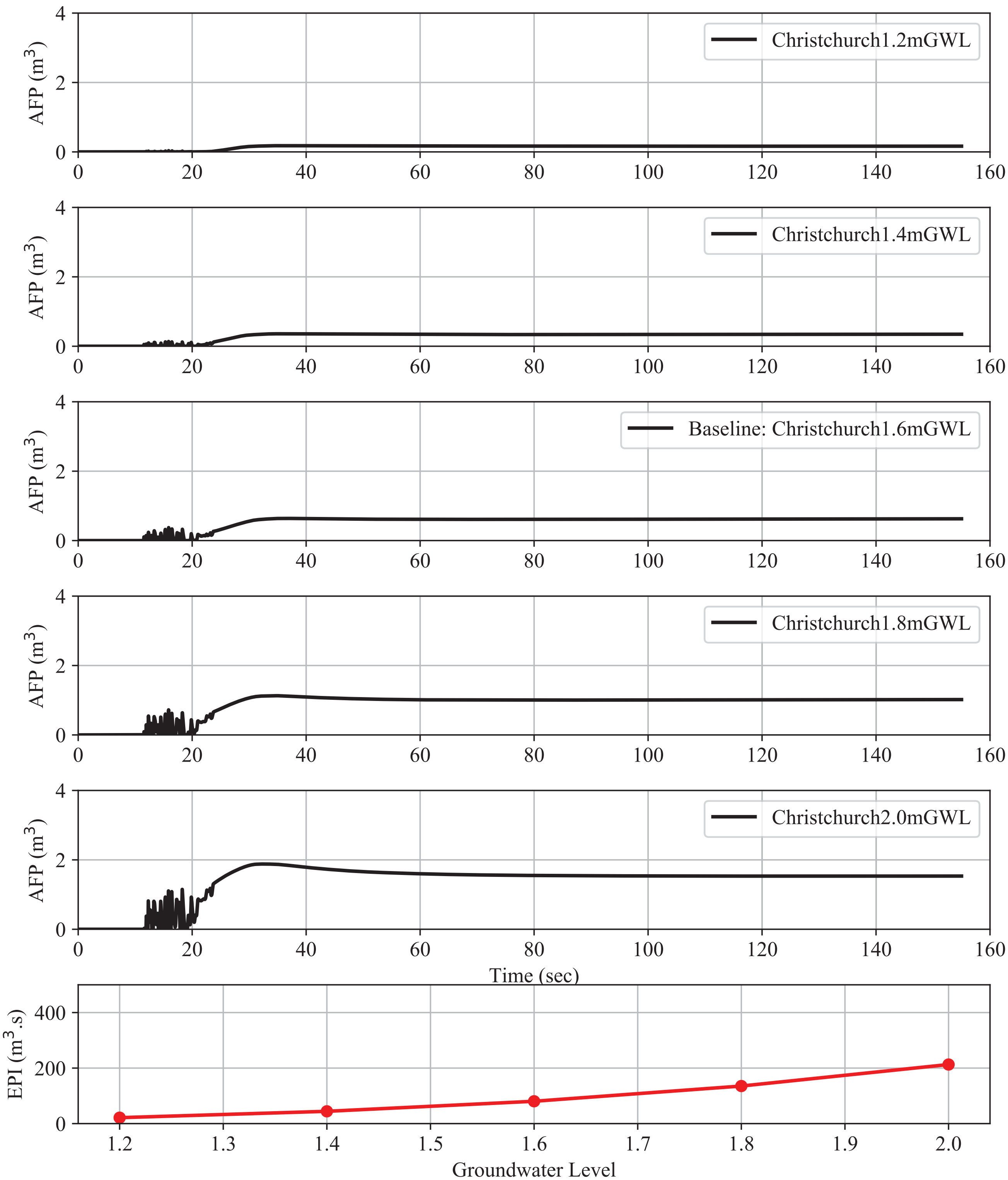
Findings:

1. Deeper GWL reduces the EPI value because the thinner liquefied layer has resulted.
2. There is a GWL associated with a peak EPI value. Such a GWL simultaneously causes a thicker liquefied layer to occur and increases the residual of hexc after shaking stops.
3. For sites without manifestation (i.e., St. Teresa & Gainsborough), GWL did not change the EPI value because the system does not develop upward seepage-induced secondary liquefaction at shallow depths.
4. Some sites are sensitive to GWL changes, but they are still within similar manifestation criteria (e.g., Range of EPI value of Shirley and Cashmere SW are in the range of Moderate to Extreme).
5. Some sites are sensitive to GWL changes, where slightly deeper GWL produces zero EPI value (e.g., Rydal reserve and Ti Rakau). The dynamic response of the site caused this condition. Deep liquefaction occurs and reducing the CSR at shallow depths. However, as GWL deeper, the CRR at shallower elevation increase and the soil generate lower hexc. Upward seepage still can increase the hexc, but they are not sufficient to cause secondary liquefaction.

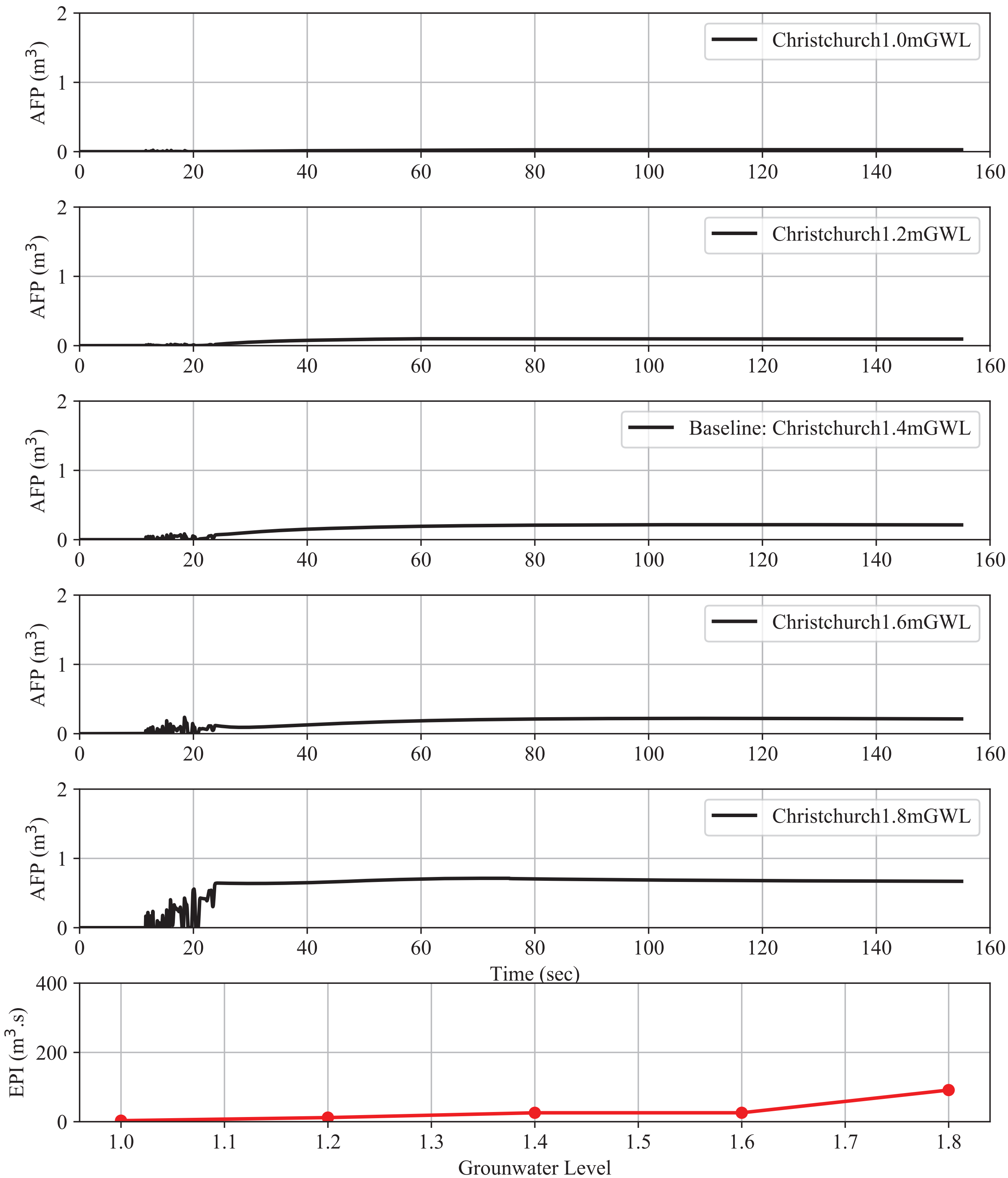
Groundwater Level Sensitivity Analysis - Avondale Park



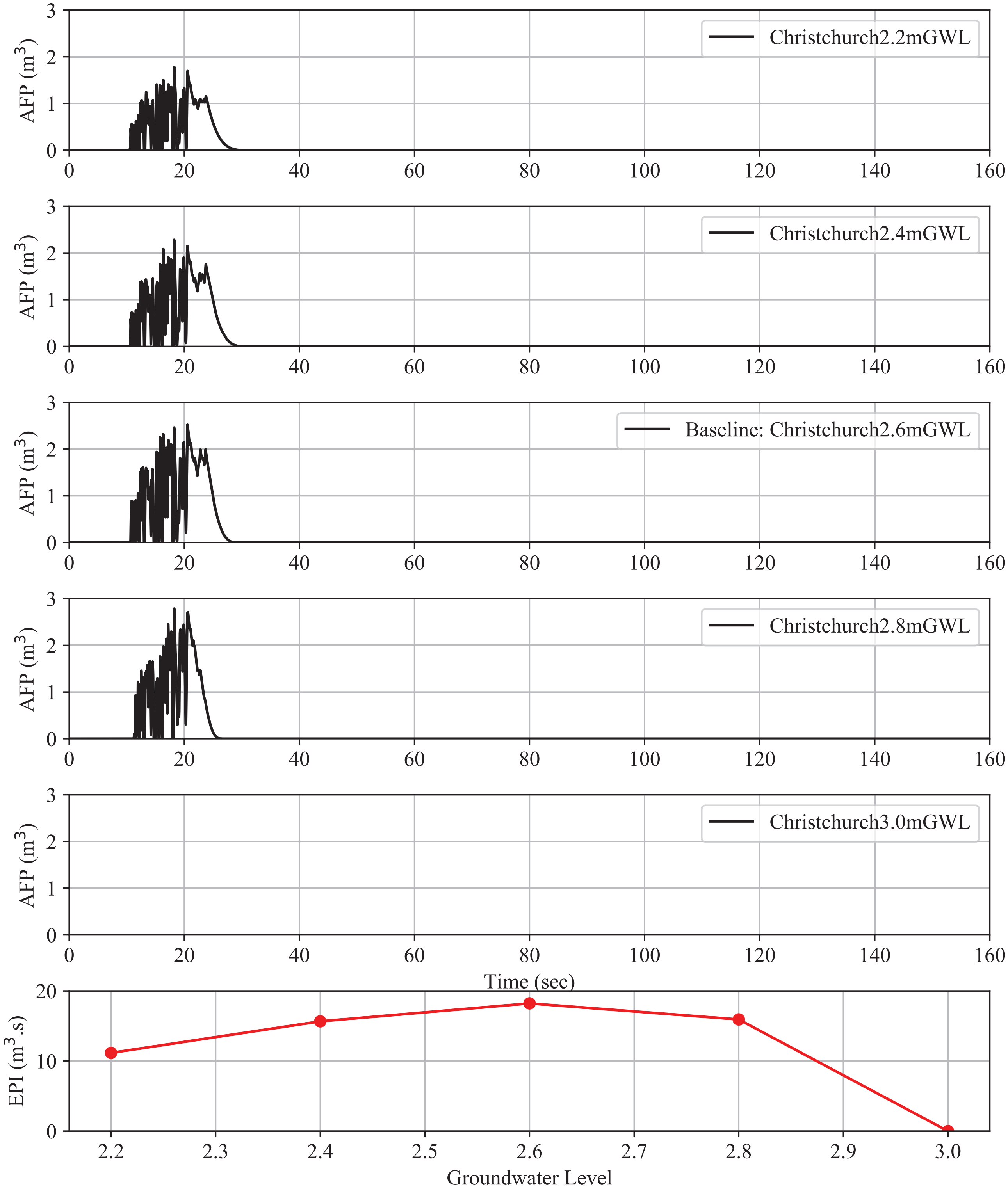
Groundwater Level Sensitivity Analysis - Barrington Park



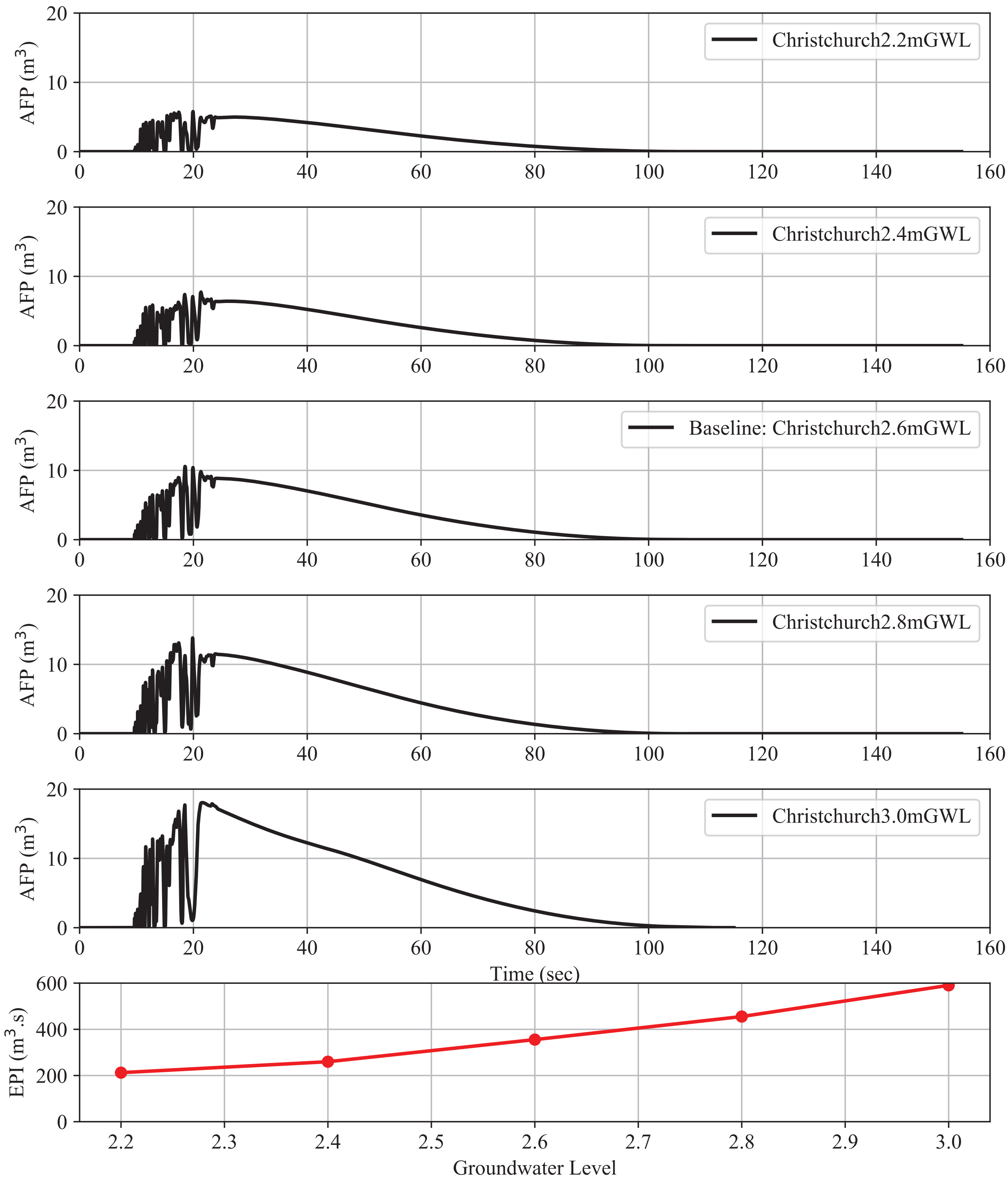
Grounwater Level Sensitivity Analysis - Brougham Street



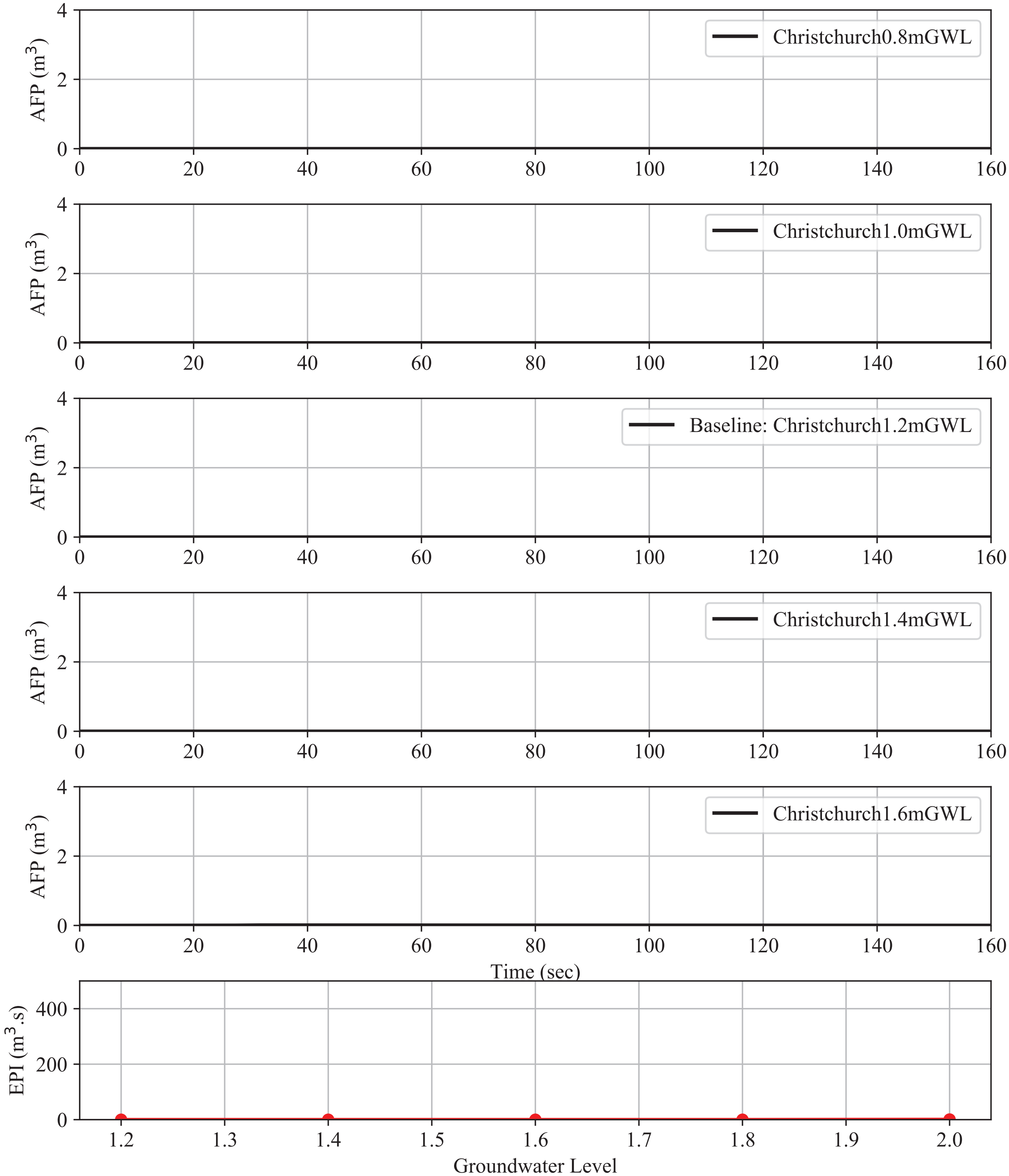
Groundwater Level Sensitivity Analysis - Carisbrooke



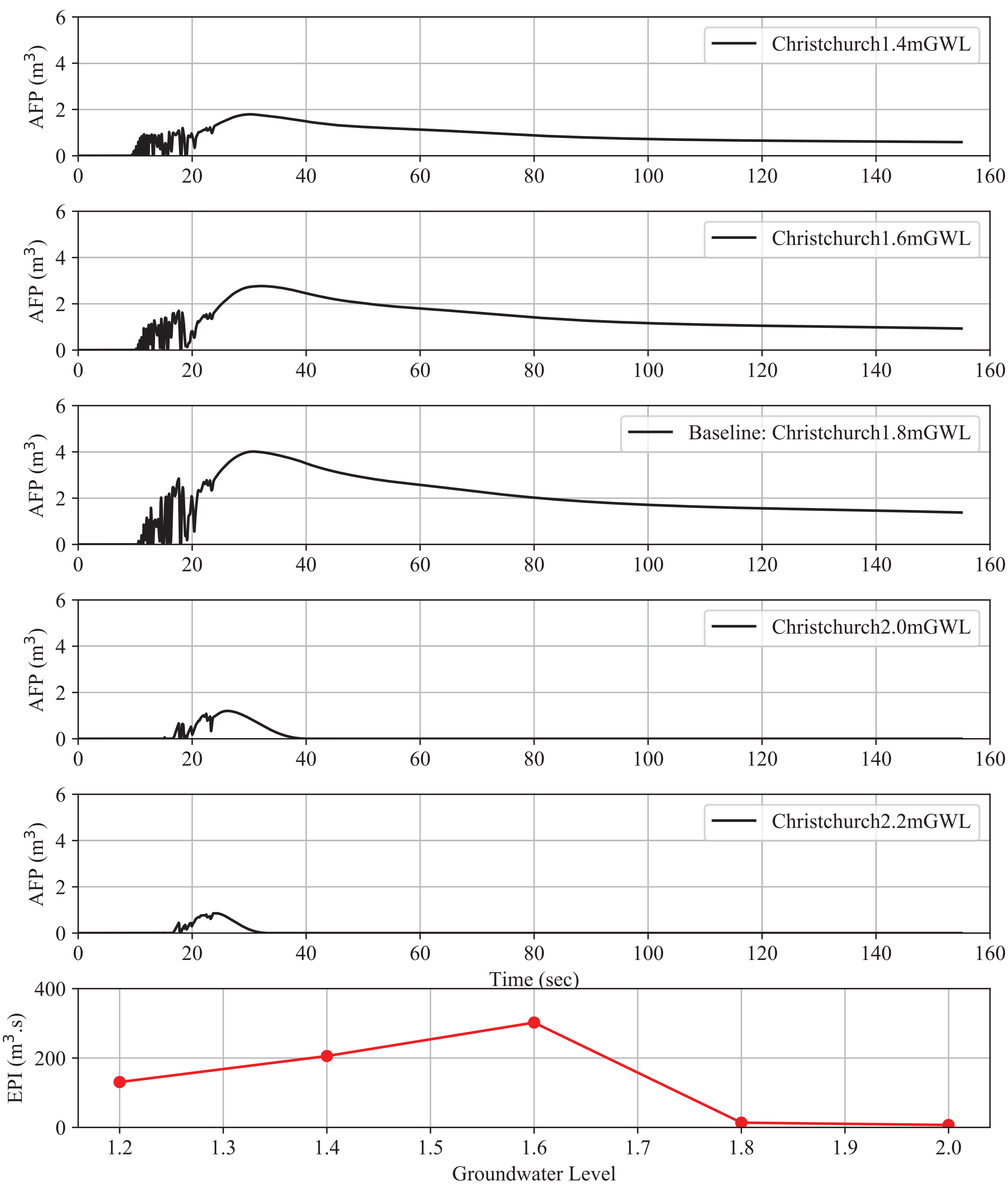
Groundwater Level Sensitivity Analysis - Cashmere SW



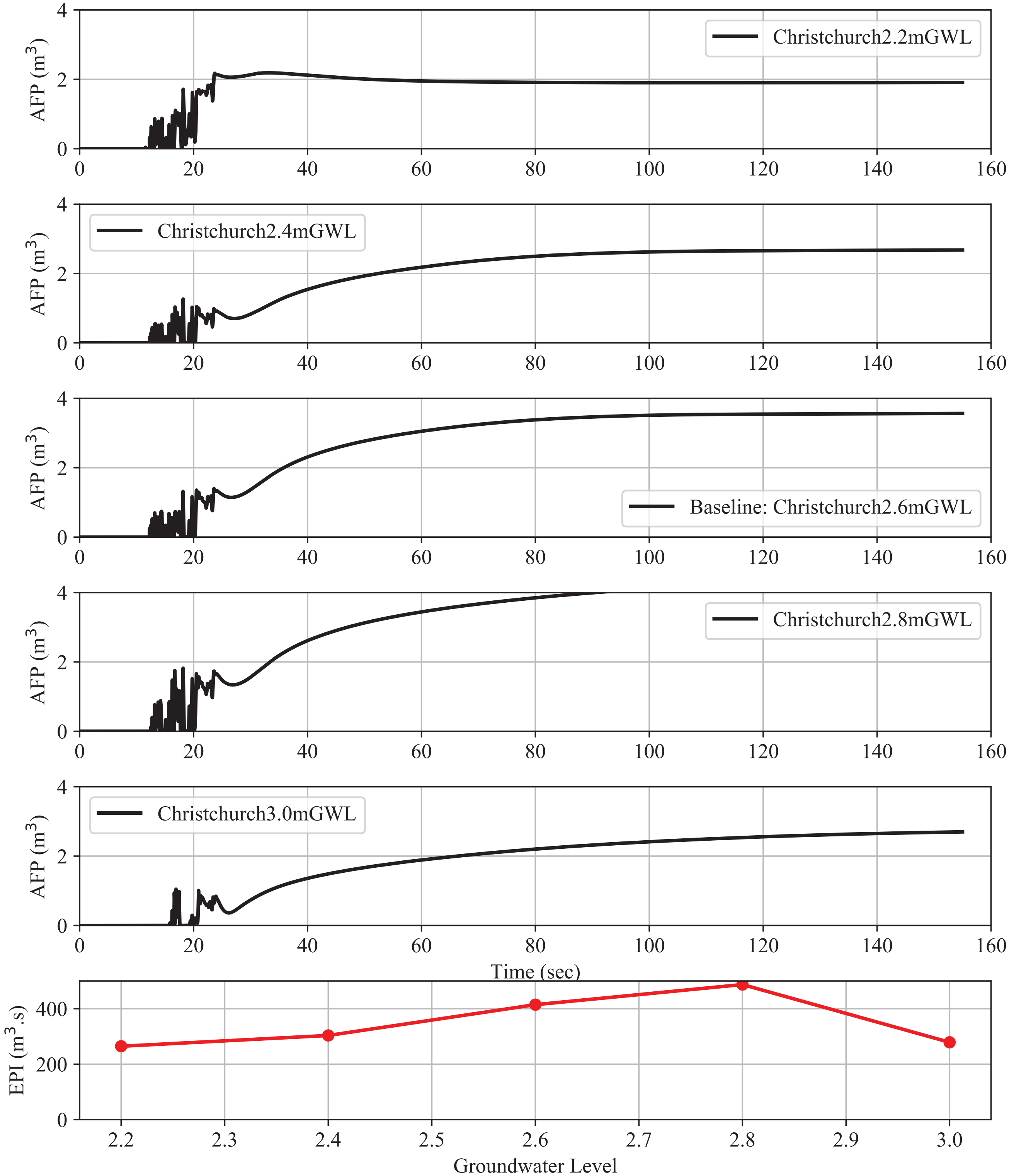
Groundwater Level Sensitivity Analysis - Gainsborough Reserve



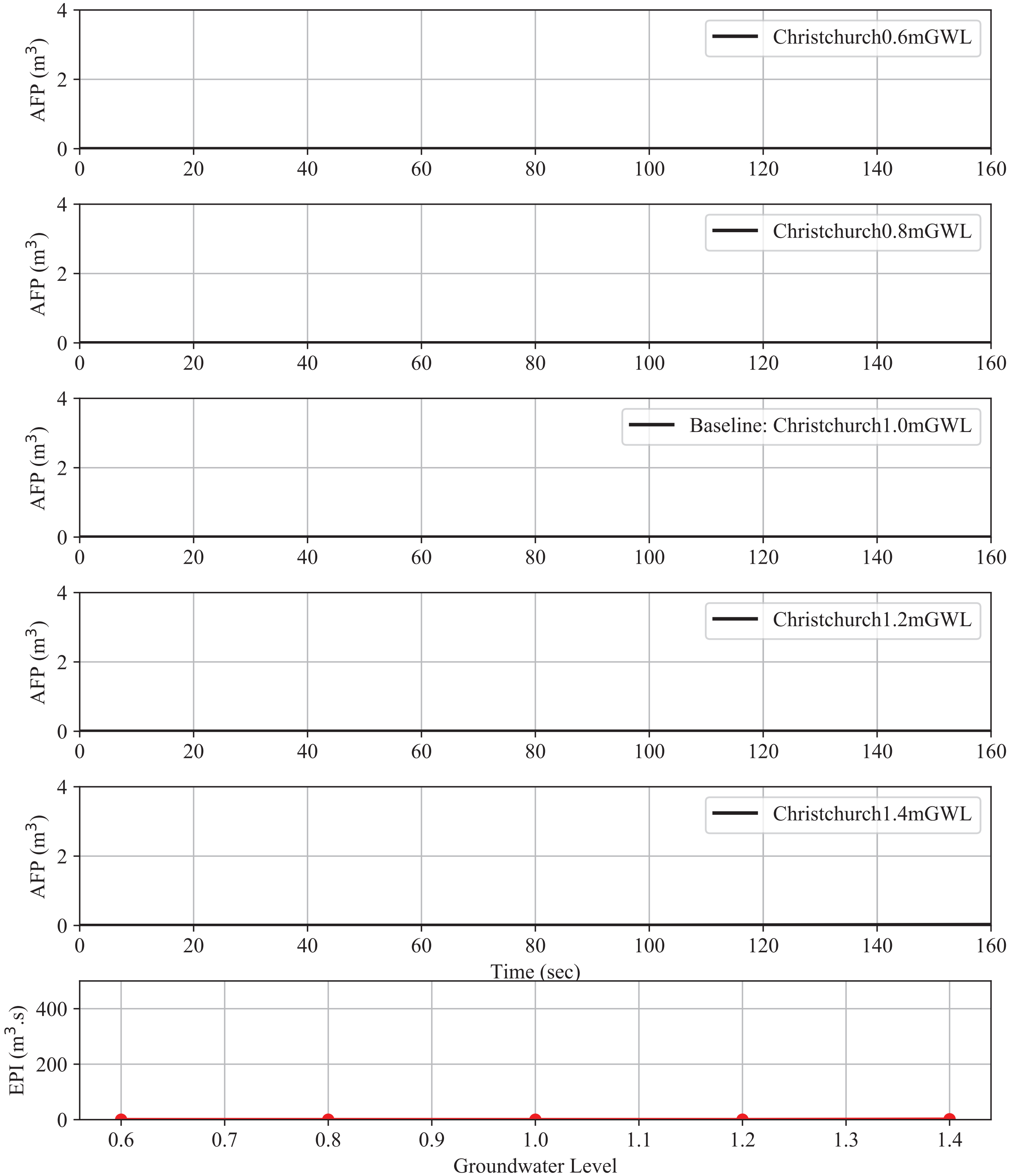
Groundwater Level Sensitivity Analysis - Rydal Reserve



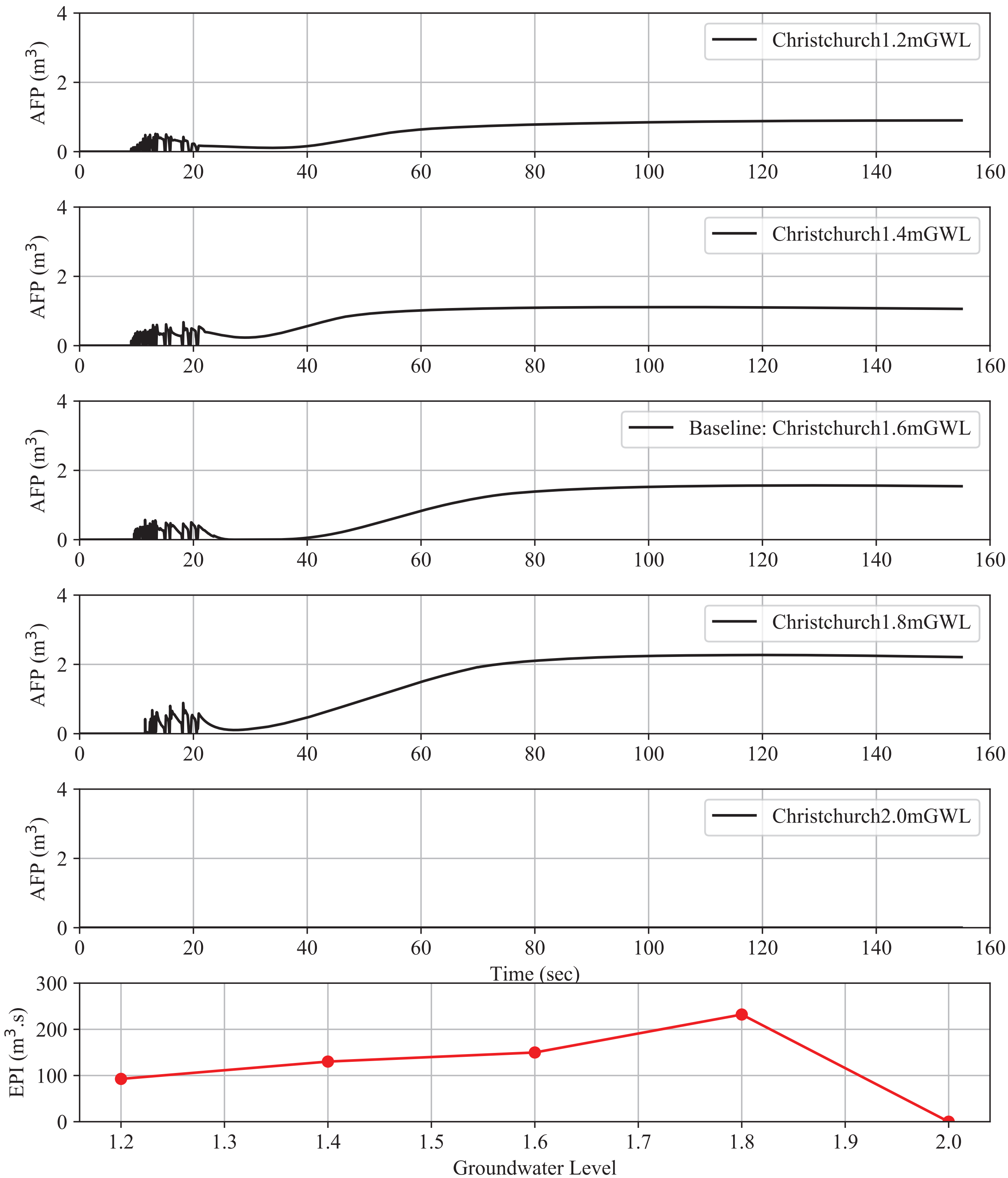
Groundwater Level Sensitivity Analysis - Shirley School



Groundwater Level Sensitivity Analysis - St. Teresa



Groundwater Level Sensitivity Analysis - Ti Rakau Reserve



Palinurus-1 and Palinurus-2 Sites

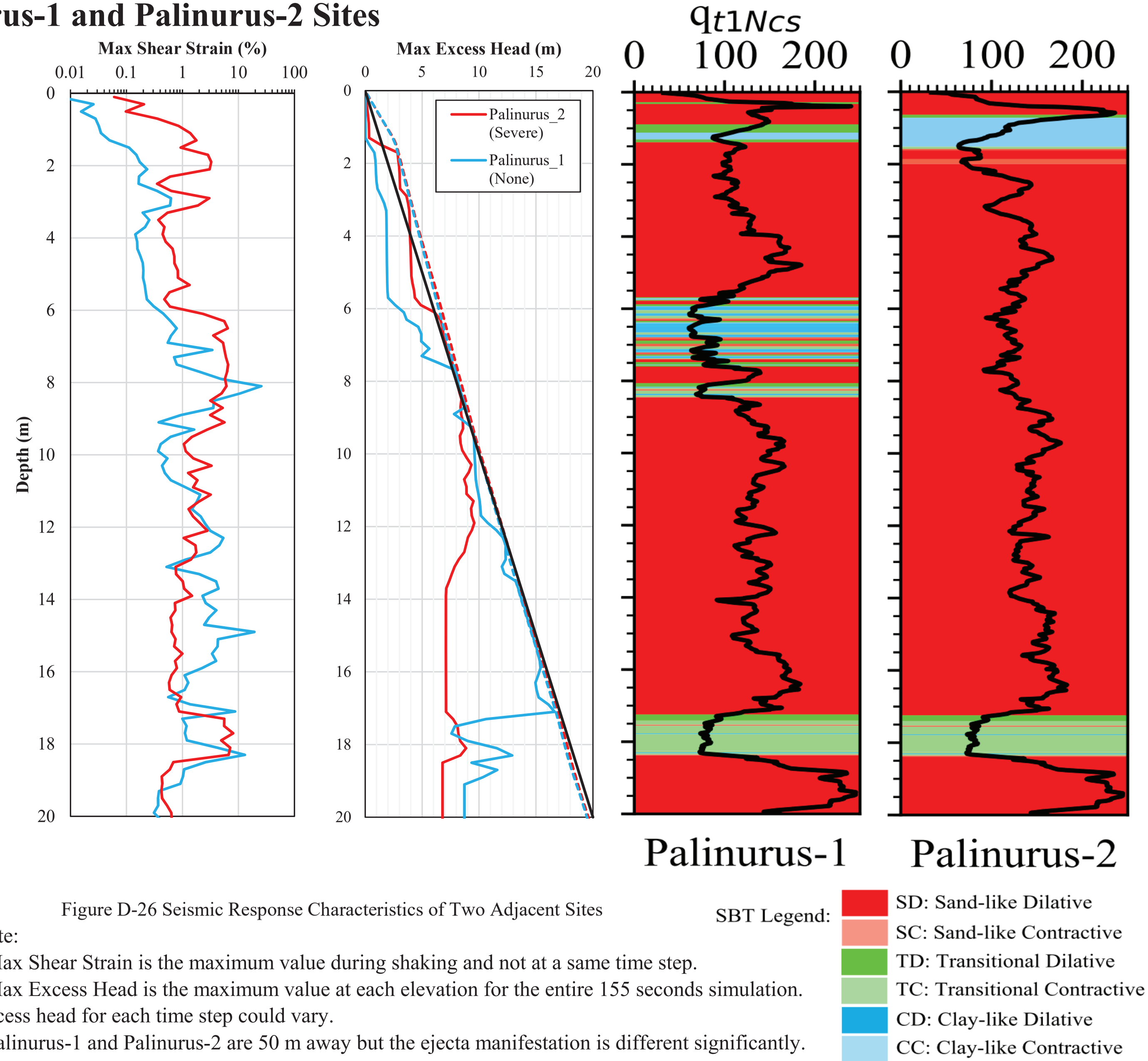


Figure D-26 Seismic Response Characteristics of Two Adjacent Sites

Note:

- Max Shear Strain is the maximum value during shaking and not at a same time step.
- Max Excess Head is the maximum value at each elevation for the entire 155 seconds simulation. Excess head for each time step could vary.
- Palinurus-1 and Palinurus-2 are 50 m away but the ejecta manifestation is different significantly.

CMHS and Cashmere SW

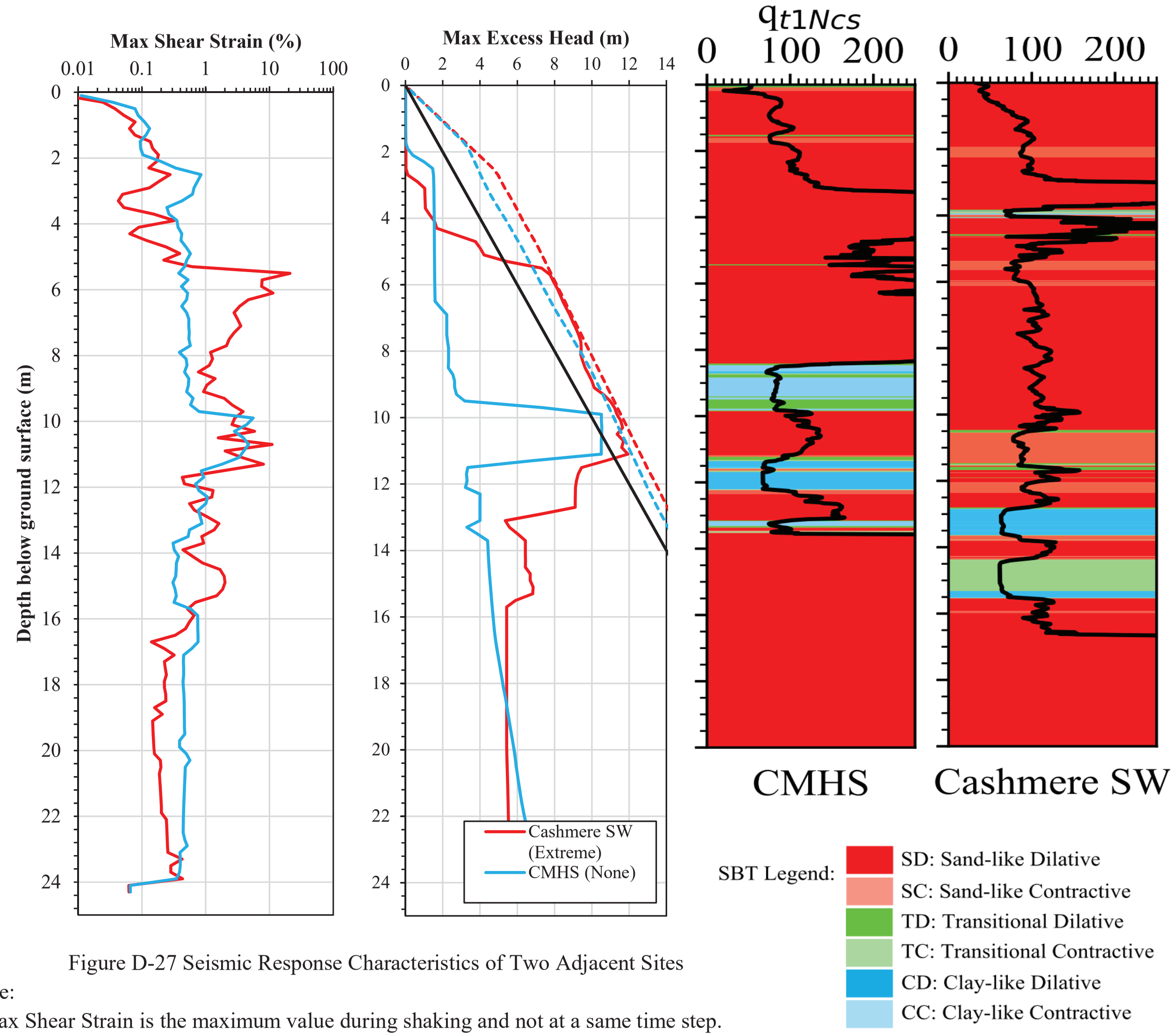


Figure D-27 Seismic Response Characteristics of Two Adjacent Sites

Note:

- Max Shear Strain is the maximum value during shaking and not at a same time step.
- Max Excess Head is the maximum value at each elevation for the entire 155 seconds simulation. Excess head for each time step could vary.
- Cashmere SW and CMHS are 100 m away but the ejecta manifestation is different significantly.

Hillsborough and Cresselly

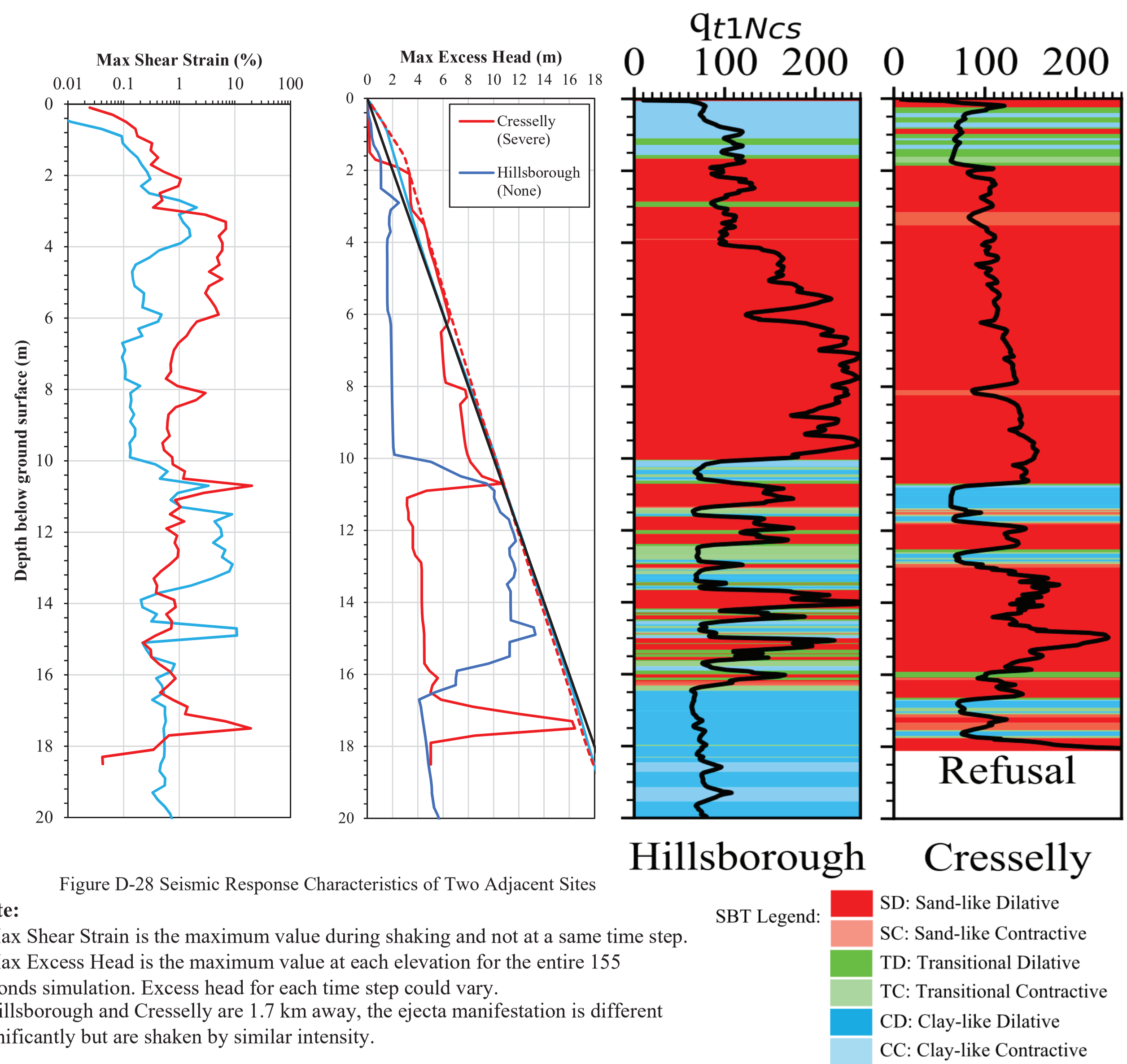


Figure D-28 Seismic Response Characteristics of Two Adjacent Sites

Note:

- Max Shear Strain is the maximum value during shaking and not at a same time step.
- Max Excess Head is the maximum value at each elevation for the entire 155 seconds simulation. Excess head for each time step could vary.
- Hillsborough and Cresselly are 1.7 km away, the ejecta manifestation is different significantly but are shaken by similar intensity.

Gainsborough and Rydal

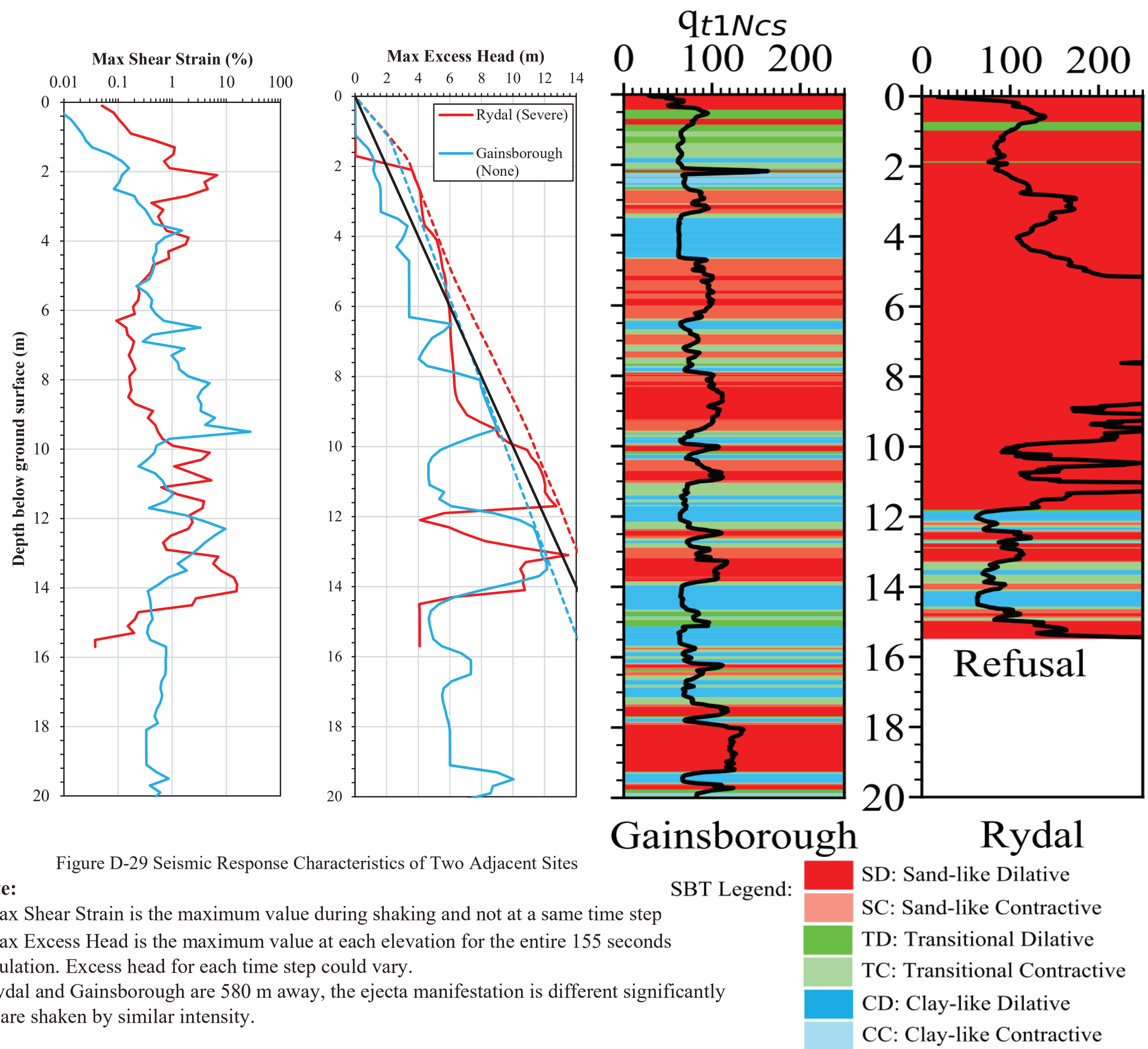
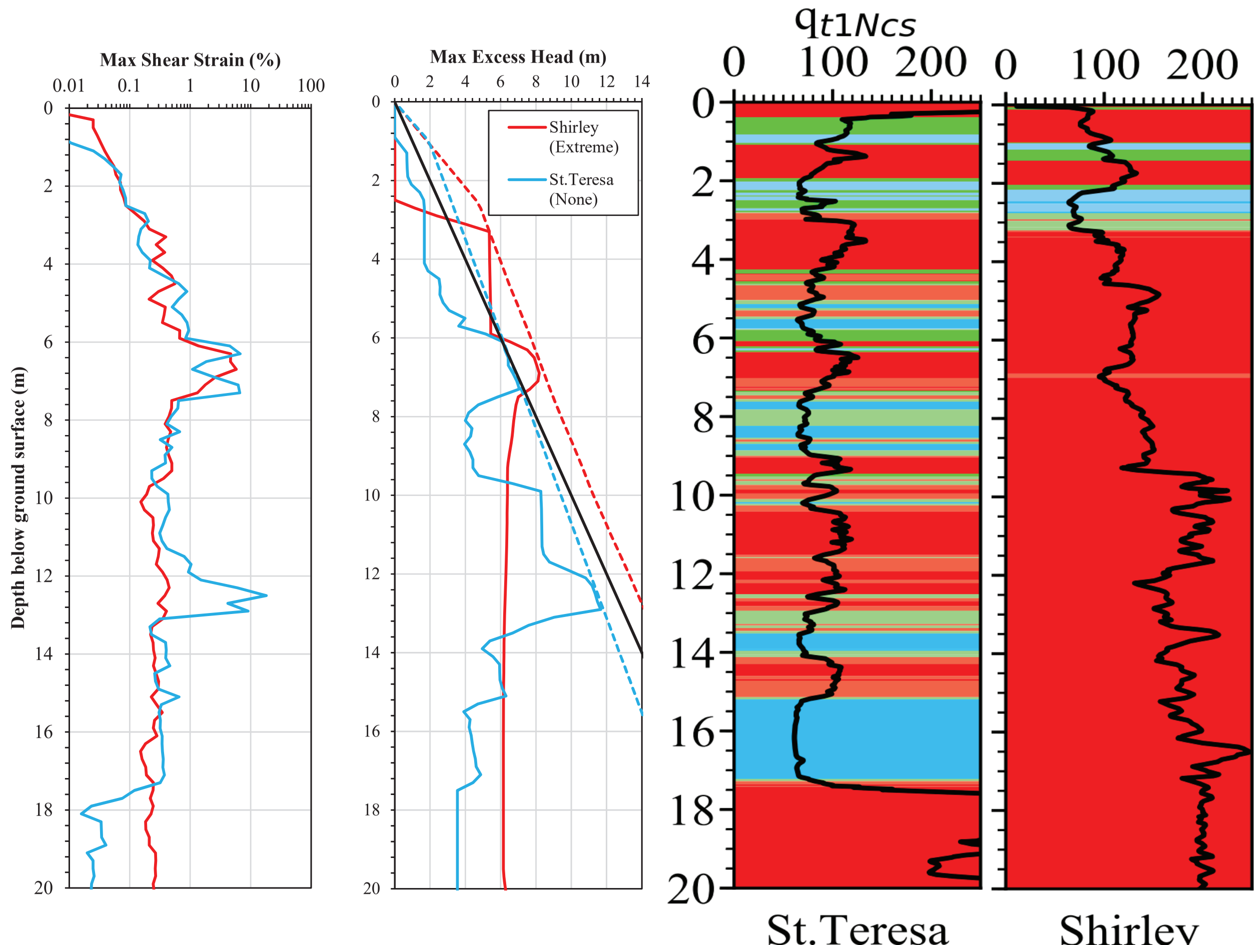


Figure D-29 Seismic Response Characteristics of Two Adjacent Sites

Note:

- Max Shear Strain is the maximum value during shaking and not at a same time step
- Max Excess Head is the maximum value at each elevation for the entire 155 seconds simulation. Excess head for each time step could vary.
- Rydal and Gainsborough are 580 m away, the ejecta manifestation is different significantly but are shaken by similar intensity.

St. Teresa and Shirley



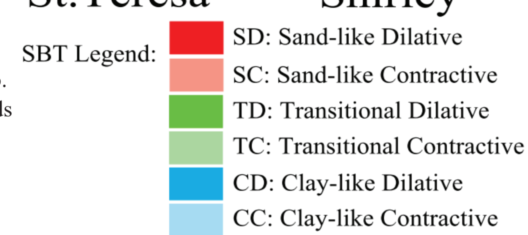


Figure D-30 Seismic Response Characteristics of Two Adjacent Sites

Note:
- Max Shear Strain is the maximum value during shaking and not at a same time step.
- Max Excess Head is the maximum value at each elevation for the entire 155 seconds simulation. Excess head for each time step could vary.
- St.Teresa and Shirley are situated on different geological formation, the ejecta manifestation is different significantly, but have similar rupture distance > 5.0 km and shaken by similar intensity.