The Ryggfonn Project

Avalanche Data from the Winters 1996/1997, 1997/1998, 1998/1999 and 1999/2000

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Summary

This report presents data collected from the full-scale Ryggfonn project during the winters 1996/1997, 1997/1998, 1998/1999 and 1999/2000. The weather and snow conditions and avalanches characteristics are summarised. The measurements obtained are briefly discussed and presented in graphs.

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1 INTRODUCTION

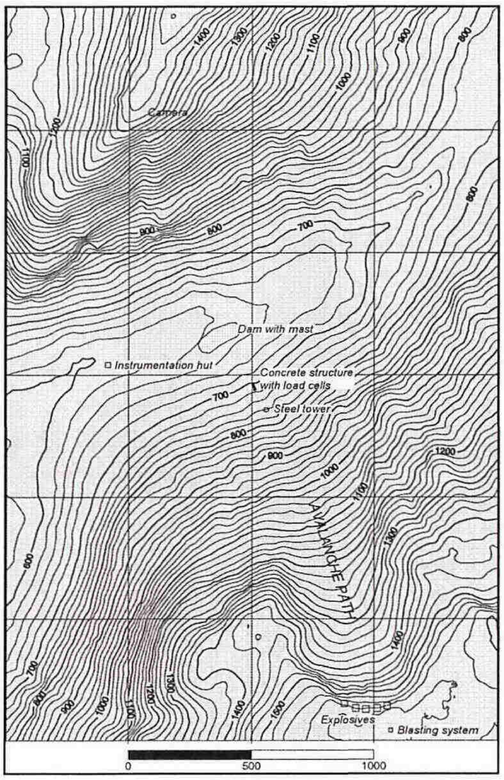

Figure 1. Map of the Ryggfonn test site.

This report covers four winters, 1996/97 through 1999/2000, and summarises the data obtained from the measurements in the Ryggfonn avalanche path.

The Ryggfonn project is a full scale experiment carried out to investigate the dynamic forces of avalanches of different types and magnitudes on fixed structures. In addition the effects of a retaining dam in the avalanche path is evaluated. The experiment site is the Ryggfonn avalanche path close to NGI's research station Fonnbu, Grasdalen, Western Norway.

The Ryggfonn avalanche usually starts from a north-facing cirque at around 1530 m a.s.l. and runs down a slightly channelled path into the valley floor below. The vertical drop from the starting zone to the runout area is around 900 m

2 OBSERVATION METHODS

Fixed installations

The installations in the lower part of the avalanche path have varied from time to time, but for most of the experiments they have consisted of the following):

- A 16 m high and 75 m wide retaining dam in the avalanche runout zone. On top of the dam is a 6.5 m high steel mast that is instrumented with strain gauges and sometimes an anemometer.
- A 4.5 m high concrete structure fitted with three load cells, each with an area of 0.72 m², situated 230 m up-slope from the dam.
- An 8.5 high tubular steel tower situated 320 m up-slope from the dam. The tower consists of four sections, each having a diameter of 1335 mm and plate thickness 15 mm.

  The tower is instrumented with strain gauges for measuring shear and moment strains at three sections, mechanical pressure indicators for every 0.5 m and a geophone for detecting the avalanches and triggering the recording system. The load data from the steel tower are given as a measure of deformation of the steel in microstrain (μS) in this report.

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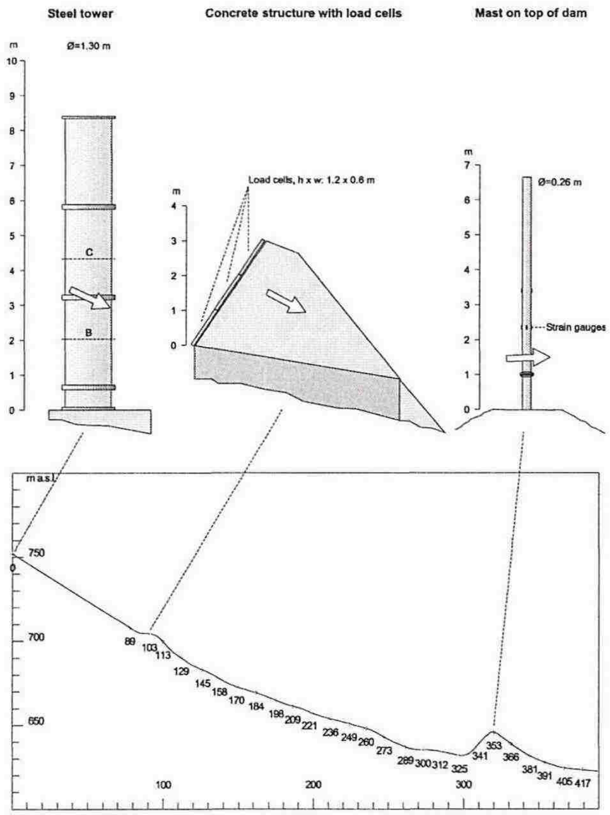

Figure 2. Fixed installations in the Ryggfonn runout area.

- Geophones placed on the ground or snow surface 50 and 100 m up-slope from the dam for the purpose of detecting the vibrations from passing avalanches.
- An instrument shelter near the runout area with recording equipment.

The data acquisition system has been changed twice during these years. Since 1998 the system consists of an IOTech Logbook with a strain gauge module DBK43A and a geophone module. For more details, consult the technical notes on instrumentation [1].

On of the main problems with the present set-up is that the installations, i.e. the steel tower, the load cells, and the geophones all have different charachteristics and sensitivity to the forces applied. It is thus difficult to compare measurements at different sites in the path. Another difficulty is that the weather and the avalanche hazard sometimes restrict the possibilities of doing surveying and other fieldwork in the runout area.

Avalanches

The avalanches studied are both natural and artificially released. In the case of natural avalanches, the recording system is started when the signal from a geophone on the uppermost construction (the steel tower) exceeds a pre-set triggering level.

Artificial avalanches are released by detonating up to five preplaced charges in the starting zone by means of a radio controlled detonating system. Typically, each charge consists of 75 to 100 kg of dynamite. If possible, artificial avalanches are videotaped and photographed with at time-lapse camera. In some cases, filming is done from the opposite mountain ridge.

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If possible, all avalanches are mapped and sometimes surveyed for area and volume calculations. The avalanches are classified according to the avalanche classification system given in the Avalanche Atlas of UNESCO/International Commission on Snow and Ice of the International Association of Hydrological Sciences, 1981[2].

Weather and snow data is recorded at NGI's field station at 930 m a.s.l., about 4 km NE of the Ryggfonn avalanche path. More detailed information about the weather, snow and general avalanche activity in the area can be found in the NGI report 20011001-5 [3].

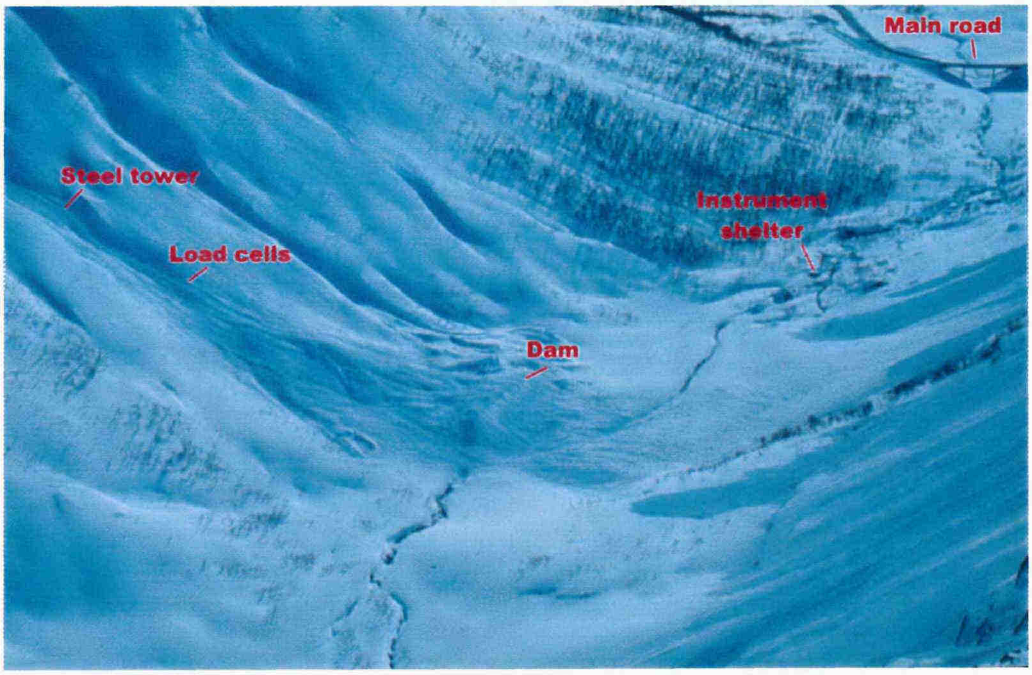

Figure 3. Overview of the Ryggfonn runout area

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3 AVALANCHE MEASUREMENTS 1996/97

3.1 General conditions

The winter 1996/1997 was characterised by unusually large amounts of winter precipitation and snow accumulation. By the beginning of April the snow height at the research station was around 400 cm. The weather conditions caused a fairly high avalanche activity in the Ryggfonn path.

Table 1. Monthly precipitation, air temperature and snow height at 930 m a.s.l.

1996/1997	Precip. (mm)	Air temperature °C.			Snow height max (cm)
		mean	max	min	
January	126.7	-5.5	2.6	-15.5	131
February	129.3	-5.8	2.4	-20.5	229
March	259.2	-5.6	2.6	-15.2	332
1.April-9.Mai	344.8	-6.0	1.2	-15.1	395

3.2 Avalanches

The following avalanches were observed the Ryggfonn avalanche path this winter:

- January 16 1997: naturally released avalanche
- January 30 1997: naturally released avalanche
- February 7 1997 at 4:16 h: naturally released avalanche
- February 8 1997 at 14:33 h: naturally released avalanche
- March 2 1997 at 12.14 h: naturally released avalanche
- March 28 1997 at 6:06 h: naturally released avalanche
- March 31 1997 at 0:44 h: naturally released avalanche
- March 31 1997 at 3:42 h: naturally released avalanche
- April 17 1997 at 14.00 h: Medium sized partly wet, artificially released avalanche.
- May 1997: Several smaller spring avalanches in the path.

3.3 The January 16 and January 30 avalanches

The first two avalanches to reach the lower Ryggfonn path did not trigger the recording system and they are thus only observed by visual inspection some time after their occurrence. Since the visual inspections are done at somewhat irregular intervals, the times of the avalanche occurrences are also uncertain.

The avalanches were comparatively small and both stopped short of the dam. The reason that these avalanches failed to trigger the recording system is probably due to low impact forces on the steel tower.

Avalanche characteristics
The January 16 avalanche was a wet, new snow avalanche. The international code is A3, B2, C2, D2, E2, F3, G2, H4, J1. This avalanche caused some build-up of debris on the lower part of the steel tower and the lowest of the three load cells.

The January 30 avalanche was also a wet, new snow avalanche. The international code is A3, B2, C2, D2, E2, F3, G2, H4, J1. The avalanche caused build-up of debris over section B and part of section C of the steel tower. The three load cells became totally covered by debris.

3.4 The February 7 and February 8 avalanches

These two avalanches occurred more or less during the same storm period and it is difficult to distinguish the individual extent of the two avalanches. The deposits of the first avalanche could not be surveyed because of the weather conditions and the danger of subsequent avalanching.

The first avalanche ran in the early morning of February 7. at 04.16 h, after a brief period of increasing southerly wind and temperatures above 0°C in the starting zone. There were no recordings from the dam because of malfunctioning sensors, but visual inspection indicates that this avalanche overran the dam.

The second avalanche ran in the afternoon the next day, February 8. at 14.33 h. By this time the wind had shifted towards west and northwest and it was accompanied by snowfall. In addition the wind speed had increased markedly causing strong snowdrift. The temperature was down to –6°C at 1000. The avalanche code for this avalanche is A1, B2, C1, D2, E2, F1, G1, H4, J1

Avalanche speeds and pressures
The time difference between the tower and load cells is 2.9 seconds for the first avalanche, which corresponds to an average speed of 35.5 m/s. For the second avalanche, the corresponding speed is considerably higher, 44.8 m/s. The moment loads at section B of the steel tower are comparable for both avalanches, around 1000 uS. Only the lower load cells functioned during both avalanches,

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and this shows a lower load for the second, and faster avalanche. This is however to be expected, since the avalanche debris would tend to build up around the lower load cells after each avalanche.

3.5 The March 2 avalanche

The avalanche occurred at 12.41 h during a brief increase of wind speed and temperature rise, following two days with heavy snowfall. The avalanche was a comparatively small avalanche, probably starting fairly low in the path. The avalanche code is A3, B3, C2, D2, E2, F3, G2, H4, J1

Avalanche speeds and pressures
The time difference between the impact registration at the steel tower and load cells is only 2 seconds, indicating a speed of more than 50 m/s. However, this time difference does probably not give a realistic speed indication, but may be due to low initial forces that failed to trigger the recording system, or possibly that the avalanche front missed the tower.

The forces on the constructions are relatively small; the maximum loads on the two load cells are around 40 kPa.

3.6 The March 28 avalanche

This small avalanche occurred at 6.06 h, after two days with new snow accumulation, combined with snowdrift and SW winds.

Avalanche speeds and pressures
Only low load values were measured at the constructions.

3.7 The March 31 avalanches

These two avalanches occurred less than 3 hours apart, the first one at 0.44 h, and the second at 03.42 h. after a marked rise of the air temperature. The loads measured are not particularly high for any of the avalanches and the impact times are ambiguous and do not give realistic speed estimates. The avalanche code is A3, B3, C2, D2, E2, F3, G2, H4, J1

3.8 The April 17 avalanche

A joint experiment was carried out in April 1997 by NGI and FBVA/AIATR, Austria, to measure avalanche forces and velocities [4]. A Pulsed Doppler Radar in a mobile version was used by the Austrian Institute of Avalanche and Torrent Research (AIATR) for the measurement of avalanche dynamics.

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Weather conditions and snow properties

An avalanche was successfully released on the 17th of April 1997 by blasting 100 kg dynamite at the top cornice. The week before the avalanche release there was a new snow accumulation of about 15 cm. The air temperature rose to above freezing in the runout zone below 1200 m a.s.l. during the day before the avalanche. At the time of the avalanche on the 17 the 0°C isotherm was at about 1000 m a.s.l.

The avalanche released initially as a dry slab avalanche that entrained gradually moister surface snow on its way down the track. The avalanche passed the steel tower and the load cells, but stopped in the catchment area in front of the dam. The debris was split and diverted by the deposits from previous avalanches and the maximum height of the deposit in front of the dam was about 3 m. In this area the avalanche deposit consisted of partly wet snow blocks, and the average density of the uppermost 150 cm in a sample pit in the debris was 540 kg/m^3. The estimated volume of the avalanche was approx. 40.000 m^3. The avalanche code is A2, B2, C1, D2, E7, F3, G7, H1, J4.

Avalanche speeds and pressures measured on the fixed installations

From the steel tower to the load cells, a stretch of 103 m, the time difference between impacts is 2.9 s, suggesting an average velocity of 35.5 m/s. The maximum moment stress at the tubular steel tower was at the middle section B and the moment caused a deformation of the steel of around 200 μS. Because avalanches earlier in the winter had caused a build-up of avalanche debris of about 3 m around the tower, the main load was applied fairly high up on the construction. There was also a similar build up around the load cells. Unfortunately, because of a damaged load cell, there were no data from the uppermost load cell. Of the two lower cells, the middle one receives the highest load (maximum value 110 kPa).

Radar measurements

The average front velocity between the tower and the load cells, calculated from the front velocity measurements of the radar, is 30 m/s. As mentioned above, the impacts on the tower and load cells suggest a speed of 35.5/s. The first impact at the load cells is at 2.9 s after the impact on the tower, while a peak is recorded at 3.47 s. This time difference corresponds with the speed calculated from the radar measurements. Since the radar can only detect the dense flow part of the avalanche, the speed of the cloud could not be recorded.

The measurements started at 900 m where the avalanche was moving fast. The avalanche front comes to a halt after 25 seconds, but even after 110 seconds there is still moving snow in the path. For a distribution of the velocities along the track, and other details of the radar measurements, consult the report by Rammer et al. [4].

4 AVALANCHE MEASUREMENTS 1997/98

The recording system was upgraded from a DAT-recorder to a solid state Campbell CR10X Datalogger with a sampling rate of 62.5 Hz.

4.1 General conditions

The winter 1997/1998 had about normal amounts of winter precipitation and snow accumulation. For most of March the snow height at the research station remained at around 200 cm. The avalanche activity in the Ryggfonn path and elsewhere in the region was moderate.

Table 2. Monthly precipitation, air temperature and snow height at 930 m a.s.l.

1997/1998	Precip. (mm)	Air temperature °C. mean	max	min	Snow height max (cm)
January	151.2	-5.1	5.8	-17	100
February	397.6	-4.3	3.5	-15.7	220
March	156.8	-6.6	4.6	-19.8	220
April	16.8	-3.0	5	-10.2	184
May	87.3	0.4	7.4	-5.8	150

4.2 Avalanches

The following avalanches were observed in the Ryggfonn path this winter:

- February 9 1998 at 7:32 h: naturally released wet snow avalanche
- February 23 1998 at 12:46 h: small wet snow avalanche
- March 26 1998 at 16:57 h.: small mixed snow avalanche

4.3 The February 9 avalanche

The avalanche occurred at 7:32 h after about 12 hours of snowfall, during a marked rise of wind speed and temperature. The avalanche was a comparatively small wet avalanche, probably starting fairly low in the path.

The avalanche code is A3, B3, C2, D2, E2, F3, G2, H4, J1

Avalanche speeds and pressures
The forces on the constructions are relatively small; the maximum load on the load cells, of which the lower receives the highest load, is around 100 kPa.

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The time difference between the impact registration at the steel tower and load cells is 8 seconds, indicating a low speed of 13 m/s. The avalanche stopped at the dam.

4.4 The February 23 avalanche

Another small and slow avalanche occurred at 12:46 h on February 23, after two days with new snow accumulation and a brief temperature rise to above 0°C in the starting zone.

The forces on the constructions are relatively small; the maximum load on the load cells, of which the uppermost load cell receives the highest load, is around 80 kPa. The time difference between the impact registration at the steel tower and load cells indicates a speed of 16 m/s. The avalanche stopped short of the dam.

4.5 The March 26 avalanche

This avalanche was also a comparative small avalanche, judging from the loads exerted on the constructions. The maximum load on the load cells (upper) was around 70 kPa. Because of the weather conditions and the danger of avalanches, the debris could not be surveyed.

Part of the avalanche, or possibly the dust cloud, seems to have reached the dam. This is indicated by a faint response of the strain gauge on the mast at the top of the dam. The impact times are ambiguous. The impact at the steel tower and the load cells indicate an average speed of 15 m/s. However, the impact indications on the mast at the dam suggest a time difference between the load cell and the dam of only 2.3 seconds, which is a clearly unrealistic value for the 250 m stretch (this would indicate a speed of 109 m/s).

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5 AVALANCHE MEASUREMENTS 1998/99

The recording system was upgraded from the Campbell CR10X Datalogger to an IOTech Logbook with a strain gauge module DBK43A and a geophone module.

The malfunctioning upper load cell was replaced. In addition, a row of five geophones was installed in the ground in front of the dam, placed from 0 to 100 m upslope from the dam top. The purpose of these was to measure the speed development of the avalanche in front of the dam.

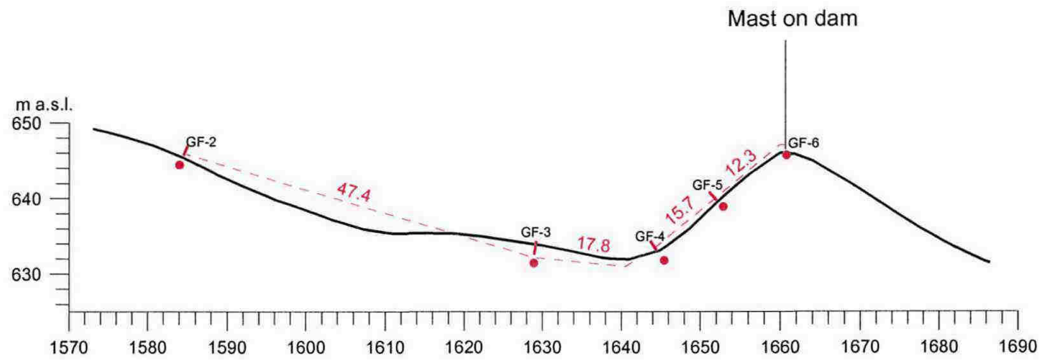

Figure 4. Geophones buried in the ground upslope of the dam

5.1 General conditions

The winter 1998/1999 had about normal amounts of winter precipitation and snow accumulation. February had the highest accumulated precipitation and by the end of this month the snow height reached it's maximum, which was 218 cm. The avalanche activity in the Ryggfonn path and elsewhere in the region was moderate.

Table 3 Monthly precipitation, air temperature and snow height at 930 m a.s.l.

1998/1999	Precip. (mm)	Air temperature °C. mean	max	min	Snow height max (cm)
November	32.7	-6.3	1.1	-13.7	51
December	198.6	-5.5	3.8	-14.6	126
January	108.8	-7.1	0.1	-18.1	106
February	253.9	-7.0	0.6	-15.9	218
March	54.4	-5.0	2.8	-14.9	199
April	172.4	-1.8	4.1	-8.9	173
May	38.8	-0.5	8.1	-7.3	145

5.2 Avalanches

The following avalanches were observed in the Ryggfonn path this winter:

- January 22 1999 at 6:03 h: Small, dry avalanche
- January 31 1999 at 16:05 h: Small wet avalanche
- February 15 1999: Mixed dry/wet avalanche

5.3 The January 22 avalanche

The avalanche occurred at 06:03 h, following three days of snow accumulation and snowdrift from the SW. The avalanche code is A3, B3, C1, D2, E1, F4, G1, H4, J1

The load exerted on the installations was moderate. The lower load cell had peak values around 100 kPa, while the loads on the two load cells above it have hardly discernible loads.

The time between impacts on the steel tower and the load cells is 6.3 seconds, suggesting a speed of 16.4 m/s. The signals from geophones in the ground in front of the dam are difficult to interpret and the signal from all the five geophones indicates the arrival of the avalanche more or less simultaneously.

The estimated time that the avalanche used between the load cells and the geophones, and between the individual geophones, is highly uncertain. The geophones do not measure any direct impact, but rather the vibrations propagating through the ground at the speed of sound. Interpreting the data, it seems that the time between first impact on the load cell to the main signal on the geophones is 17.5 seconds. The distance from the load cell to the uppermost of the geophones is 150 m, indicating an avalanche speed of 8.6 m/s.

5.4 The January 31 avalanche

This small wet snow avalanche occurred at 16.05 h in connection with a rise in temperature. The avalanche released in the lower part of the path and stopped some 70 m short of the dam. The impact on the steel tower is hardly discernible and there were no registrations on the load cells, which may have been for the most part bypassed by the slow moving avalanche.

5.5 The February 15 avalanche

The avalanche released during a period of intense snowfall and strong southerly winds. This avalanche did release in the Ryggfonn cirque itself, but came from the eastern flank of the path, around 300 m below the top ridge. The avalanche

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stopped in the lower part of the dam and the thickness of the deposit in front of the dam was 3–4 m.

It is assumed from the load measurements that only part of the avalanche hit the steel tower or the load cells, since the load values are fairly low and the fact that the avalanche released from the side of the main path. Of the load cells, the lower and the middle cell received the highest loads, up to around 80 kPa. The impact times at the steel tower and the load cells seem to indicate an avalanche speed of 17.2 ms, but this may be misleading if the avalanche front has bypassed the steel tower. From the load cells to the uppermost of the geophones the time difference is 4.9 seconds, indicating ac speed of 31 m/s.

The avalanche code (UNESCO/IAHS 1980) is: A3, B3, C7, D2, E1, F4, G2, H4, J1

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6 AVALANCHE MEASUREMENTS 1999/2000

To try to measure the speed development of the avalanche in front of the dam a row of interconnected mercury switches was placed on aluminium stakes in the snow, at set distances from the dam top. By reading the changes in the circuit caused by the consecutive toppling of the stakes, the arrival time of the avalanche front presumably can be measured.

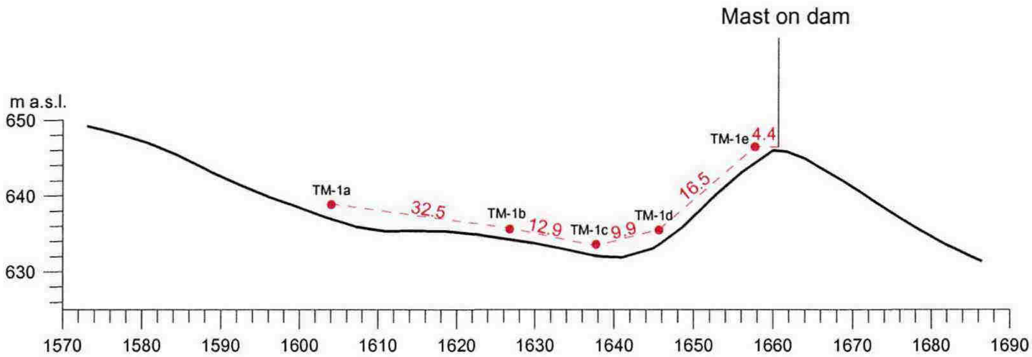

Figure 5. Time swictches on stakes placed in the snow before the avalanche

6.1 General conditions

The winter 1999/2000 was characterised by more than average winter precipitation and snow accumulation. The avalanche activity in the Ryggfonn avalanche path was nevertheless moderate with only one natural and one artificial avalanche recorded.

Table 4: Monthly precipitation, air temperature and snow height at 930 m a.s.l.

1999/2000	Precip. (mm)	Air temperature °C. mean	max	min	Snow height max (cm)
November	201.9	1.2	9.7	-8.1	109
December	156.7	-6.8	2.2	-15.2	136
January	409.8	-3.8	4.7	-14.0	308
February	209.8	-4.8	4	-14.0	386
March	238.6	-4.7	5.5	-15.8	450
April	48.3	0.1	9	-12.8	404
1.May–19 May	15.6	5.5	11.5	-1.7	292

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6.2 Avalanches

The following avalanches were observed in the Ryggfonn path this winter:

- January 11 2000 at 05.43 h: naturally released avalanche
- February 17 2000 at 13.54 h: Large dry artificially released avalanche. Avalanche code (UNESCO/IAHS 1980): A2, B2, C1, D2, E7, F3, G7, H1, J4.

6.3 The January 11 avalanche

This avalanche released from the east side of the main path, around 300 m below the top ridge. At the time, there was a moderate snowfall with a brief increase of wind from the southeast.

Only part of the avalanche hit the steel tower. This is also indicated by fact that the duration of the impact on the steel tower is much shorter compared to the load cells. The load exerted on the load cells is fairly high with a maximum load on the middle load cell of around 500 kPa.

The impact times at the steel tower and the load cells seem to indicate an avalanche speed of 31.2 ms, but this may be misleading since the avalanche front most likely has bypassed the steel tower. From the load cells to the mast on the dam, the time difference is 9.1 seconds, indicating an average speed of 16.5 m/s.

The estimated speed between the switches TM-1 a-b is: 34.9 m/s, TM-1 b-c: 25.8 m/s, TM-1 c-d: 12.3 m/s and TM-1 d-e: 20.6 m/s. Note that these values do not necessarily represent the speed of the dense flow, but rather the dust cloud.

The dense part of the avalanche did not overrun the dam, but left a freeboard of about 5 m. Avalanche debris now covered all but a part of the uppermost load cell. The steel tower had avalanche debris up to about 3.5 m.

The avalanche code is A3, B3, C1, D2, E1, F4, G1, H4, J1.

6.4 The February 17 avalanche

On February 17. there was a break in the weather with clear skies and sun. Although there had been a significant increase of snow since the avalanche on January 11, no natural avalanches had run in the Ryggfonn path since then. The snow conditions were favourable for entrainment along the avalanche path, since the top layer of the snowpack consisted of about 30 cm of new loose snow in the full length of the path. It was thus decided to release an artificial

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avalanche by detonating 100 kg of preplaced dynamite. The explosives were set off by means of the radio controlled blasting system.

As expected a fast powder avalanche was released and the dust cloud overran the dam by several hundred m far up the opposite mountain side. The avalanche was photographed from the opposite ridge and videotaped from below in the valley. The film team in the valley heard a large metallic noise as the avalanche passed the steel tower and the load cells. After the snow dust had settled it was discovered that the steel tower had been torn off at the base and had been carried to the downslope side of the dam, some 400 m below the foundation of the tower.

In addition, it turned out that the steel tower on it's way down had hit the top load cell head on and sheared off more than 1.5 m of the concrete structure supporting the load cells.

The destruction of the equipment naturally limited the amount data acquired. The upper load cell registered peak values of around 950 kPa before the broken steel tower hit it. This value is significantly higher than previously observed values.

The impact time difference between the steel tower and the top of the dam of 8.3 s, suggesting an average speed of 42.5 m/s.

The avalanche code (UNESCO/IAHS 1980) is: A2, B2, C1, D2, E7, F3, G7, H5, J4.

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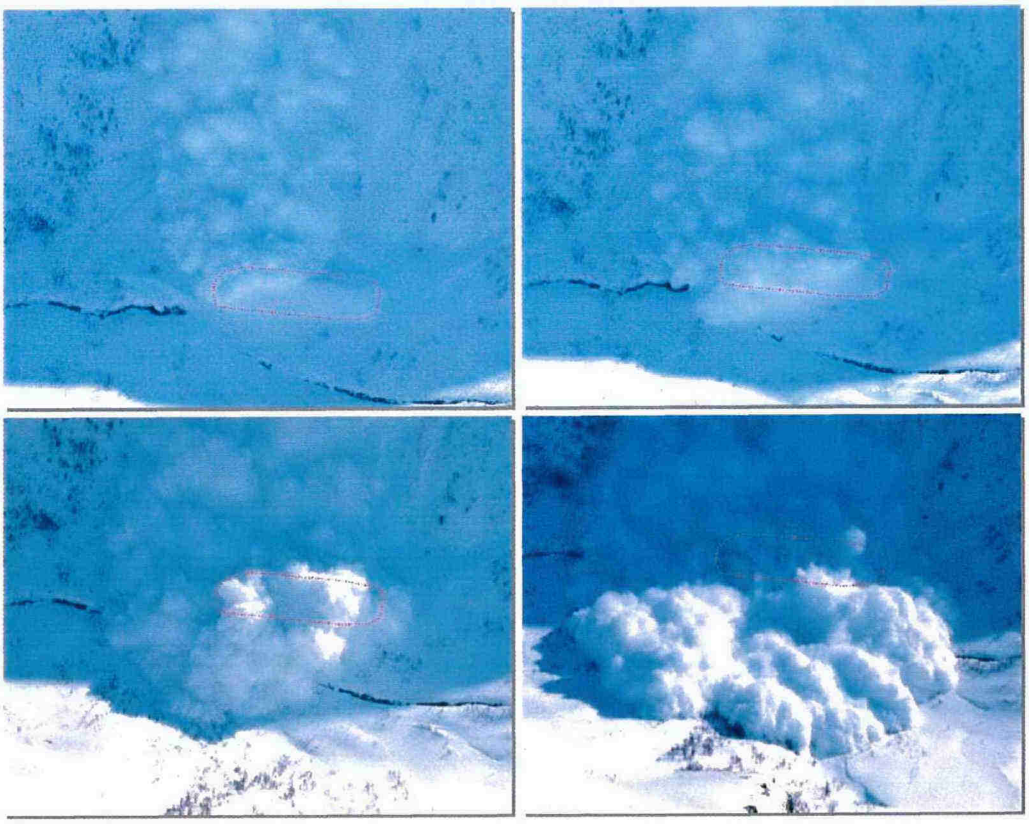

Figure 6. The avalanche overruns the dam.

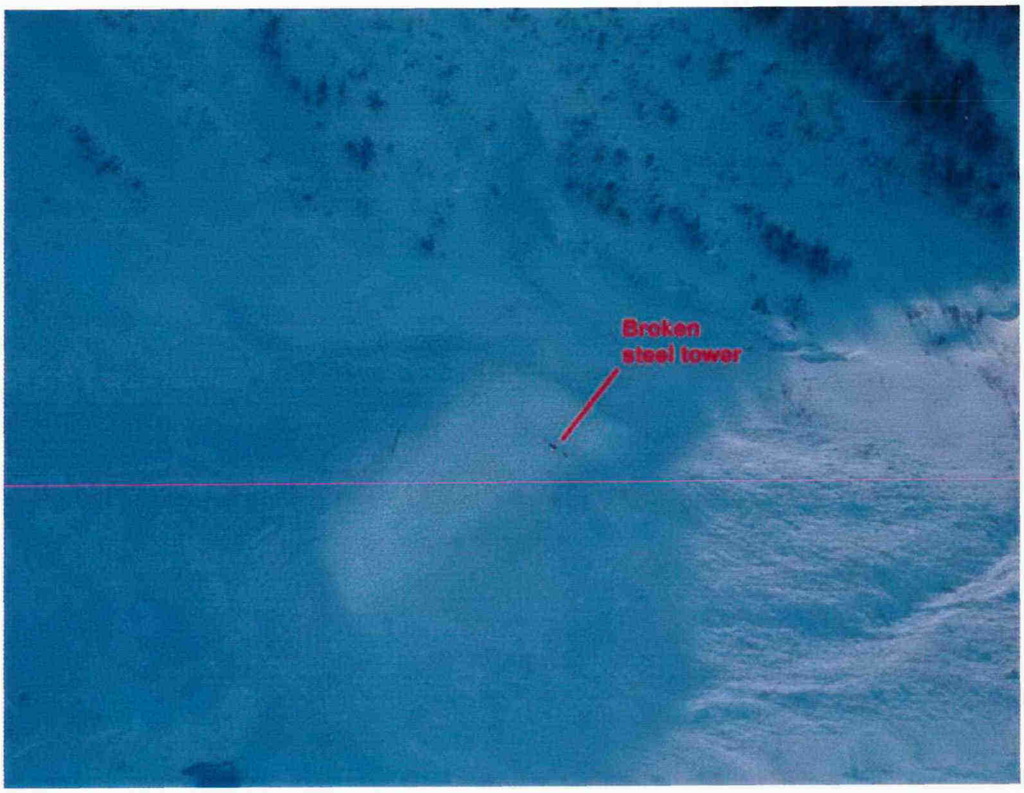

Figure 7. The dam after the February 17 avalanche.

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7 OVERVIEW OF AVALANCHE MEASUREMENTS 1996 – 2000

Date	Speed	Estimated avalanche volume in runout area	Classification (ICSI)									Impact pressures on load cells		
	Tower-load cells											Upper Peak	Middle Peak	Lower Peak
yyyymmdd	m/s	10^3 m^3	A	B	C	D	E	F	G	H	I	kPa	kPa	kPa
19970116	-	3	3	2	2	2	2	3	2	4	1	-	-	-
19970130	-	25	3	2	2	2	2	3	2	4	1	-	-	-
19970207	(35.5)	100	-	-	-	-	-	-	-	-	-	-	125	**170**
19970208	(44.8)	140	1	2	1	2	2	1	1	4	1	-	-	**70**
19970302	(50)	25	3	3	2	2	2	3	2	4	1	-	**35**	35
19970328	-	10	3	3	2	2	2	3	2	4	1	-	4	**7**
19970331	-	20	3	3	2	2	2	3	2	4	1	-	30	**55**
19970331b	-	15	3	3	1	2	2	4	1	4	1	-	35	**45**
19970417	35.5	40	2	2	1	2	7	3	7	1	4	-	**110**	65
19980209	13	15	3	3	2	2	2	3	2	4	1	40	50	**130**
19980223	16	5	3	3	1	2	2	4	1	4	1	20	85	**90**
19980326	15	10	-	-	-	-	-	-	-	-	-	**125**	70	40
19990122	16.4	1	3	3	1	2	1	4	1	4	1	50	**85**	85
19990131	-	3	3	3	2	2	2	3	2	4	1	-	-	-
19990215	17.2	30	3	3	7	2	1	4	2	4	1	15	**80**	60
20000111	31.2	100	3	3	1	2	1	4	1	4	1	380	**500**	280
20000217	>42	100	2	2	1	2	7	3	7	5	4	**950**	800	50

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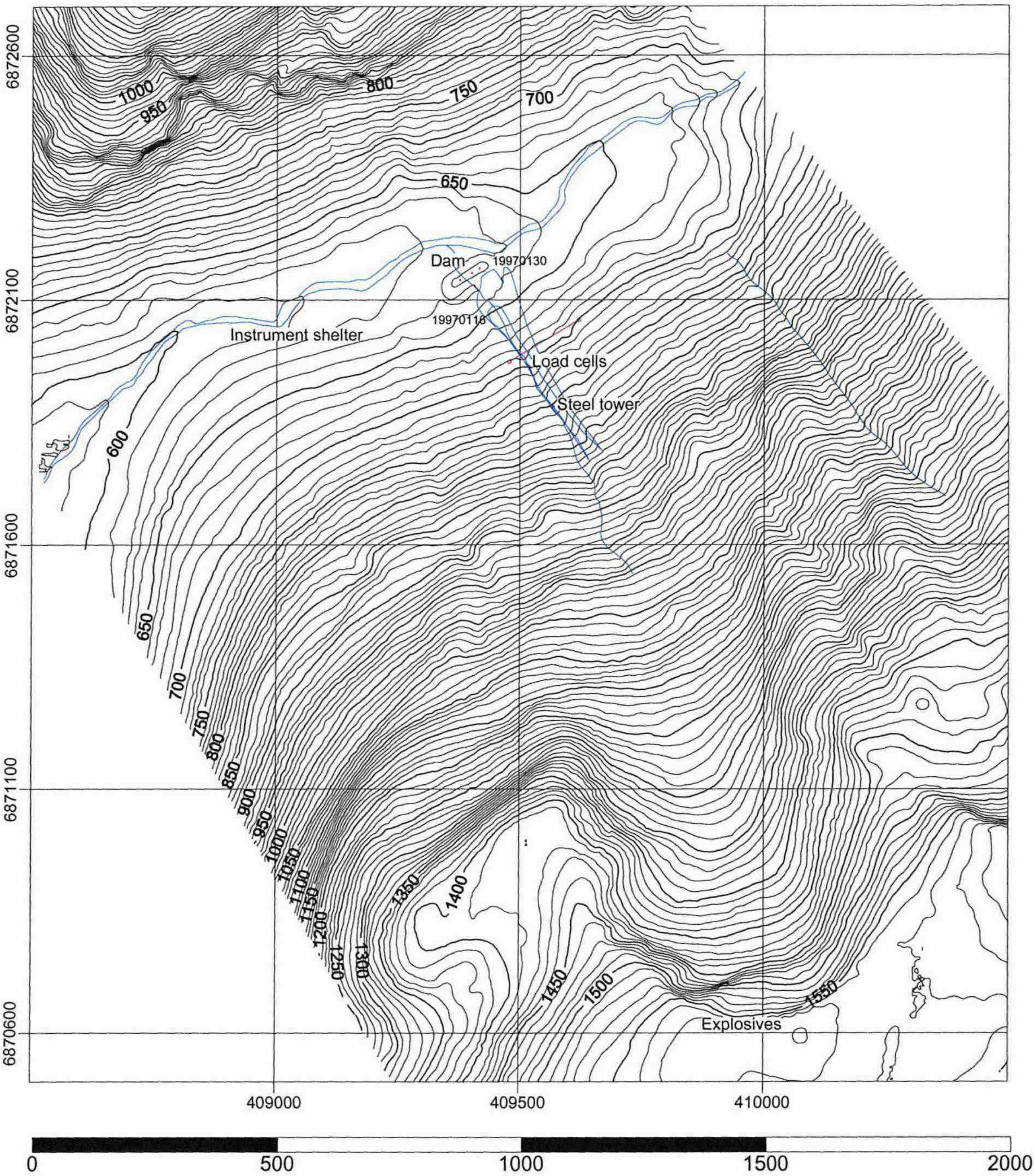
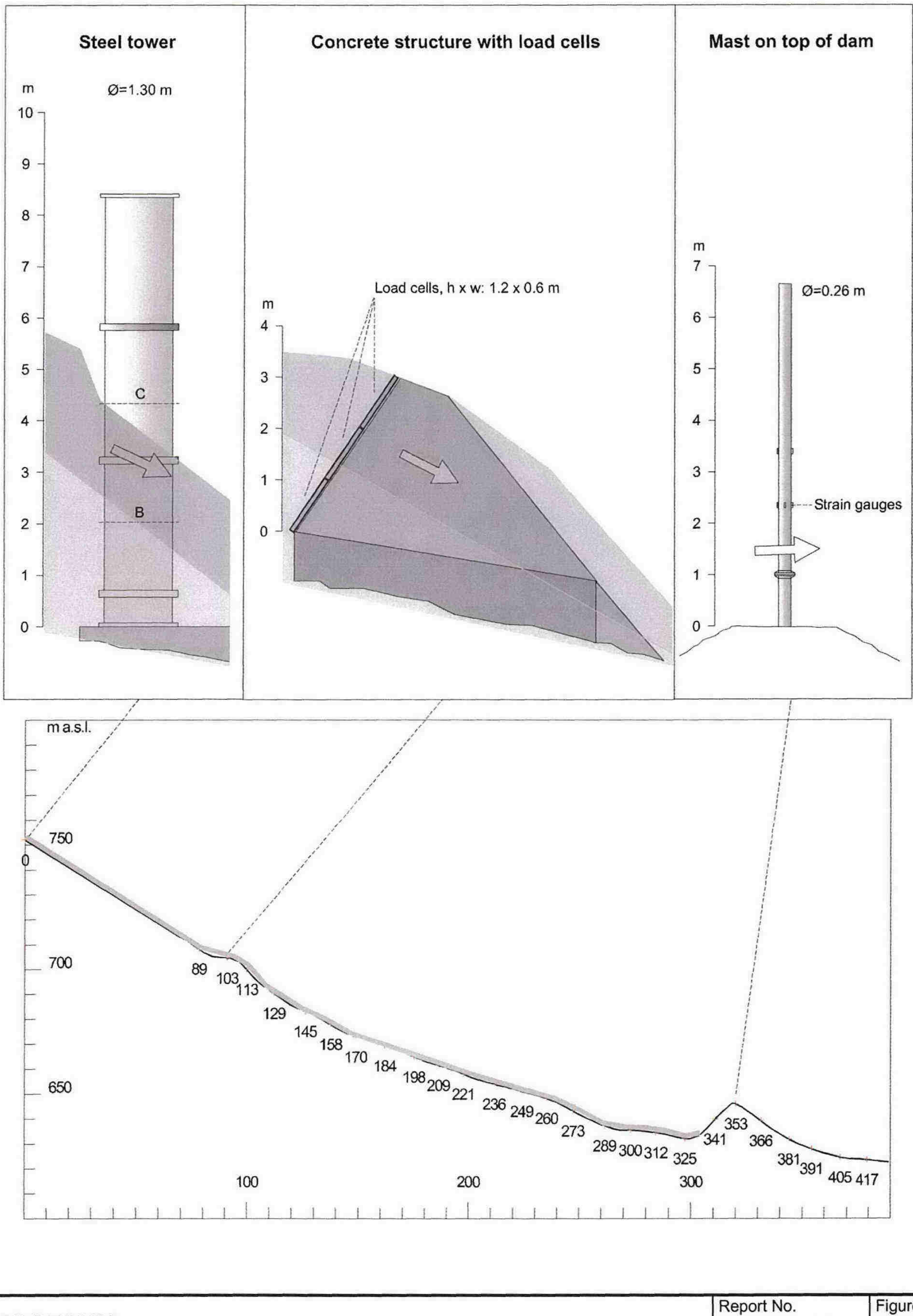


RYGGFONN	Report No. 581200-33	Figure No. 1.
Avalanches 1997-01-16 and 1997-01-30 No data were aquired from these avalanches	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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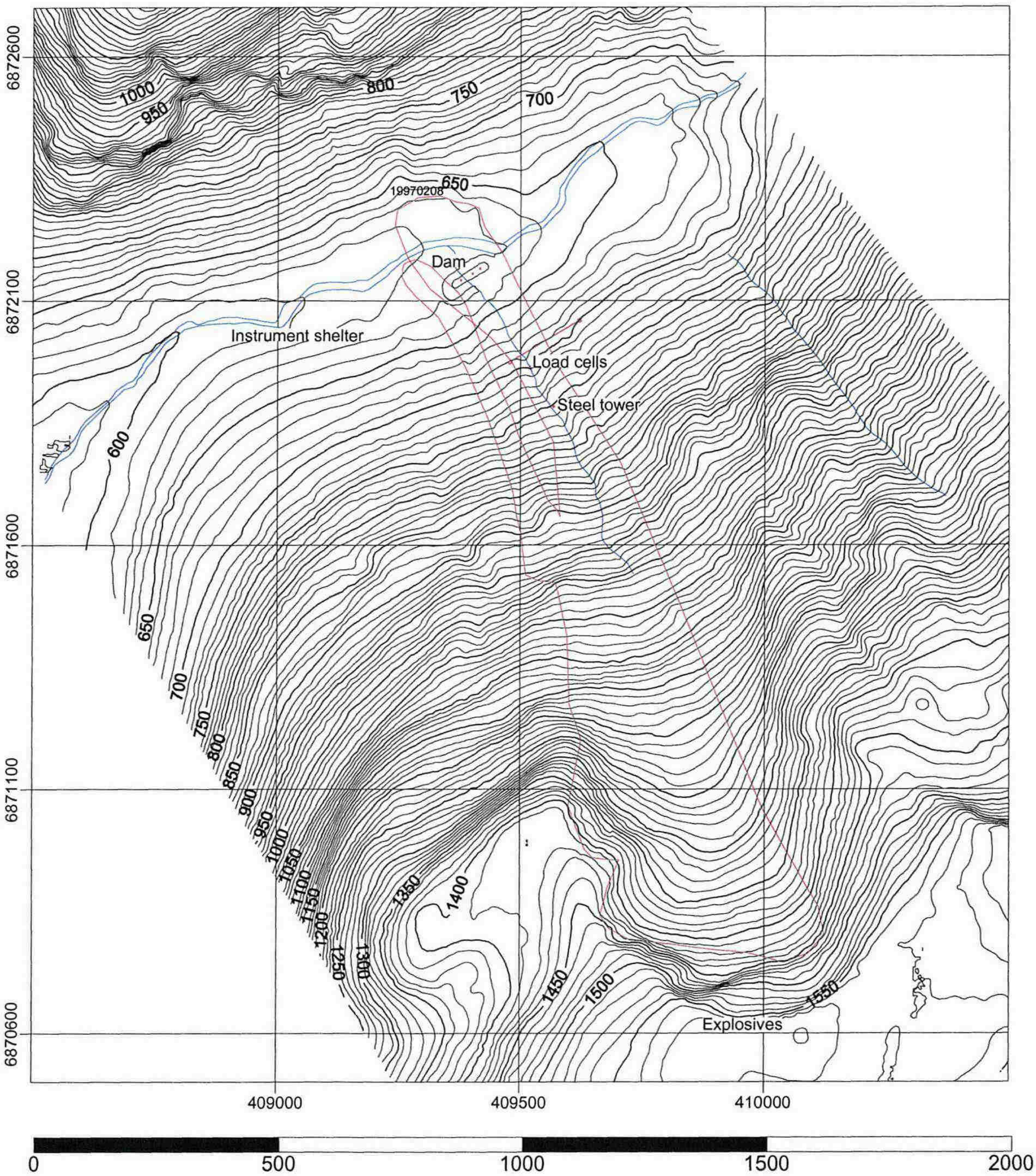
Avalanches 1997-01-16 and 1997-01-30 Distribution of avlanche debris around the constructions, observed 01-26 (lower) and 02-04 (upper)	Drawn by KKr Revised Approved	Date 2001-11-01 NGI



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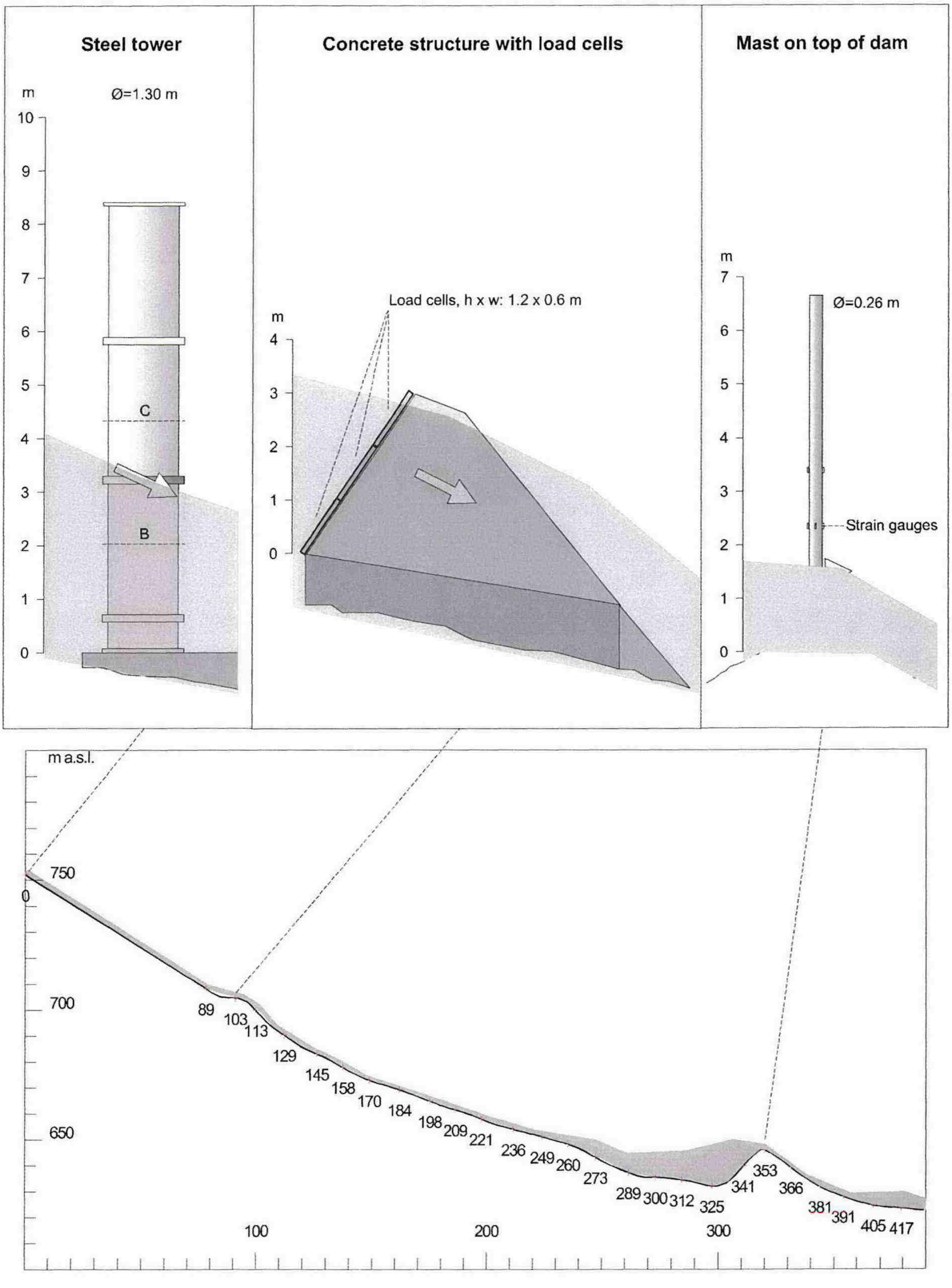
Avalanches 1997-02-07 and 1997-02-08	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



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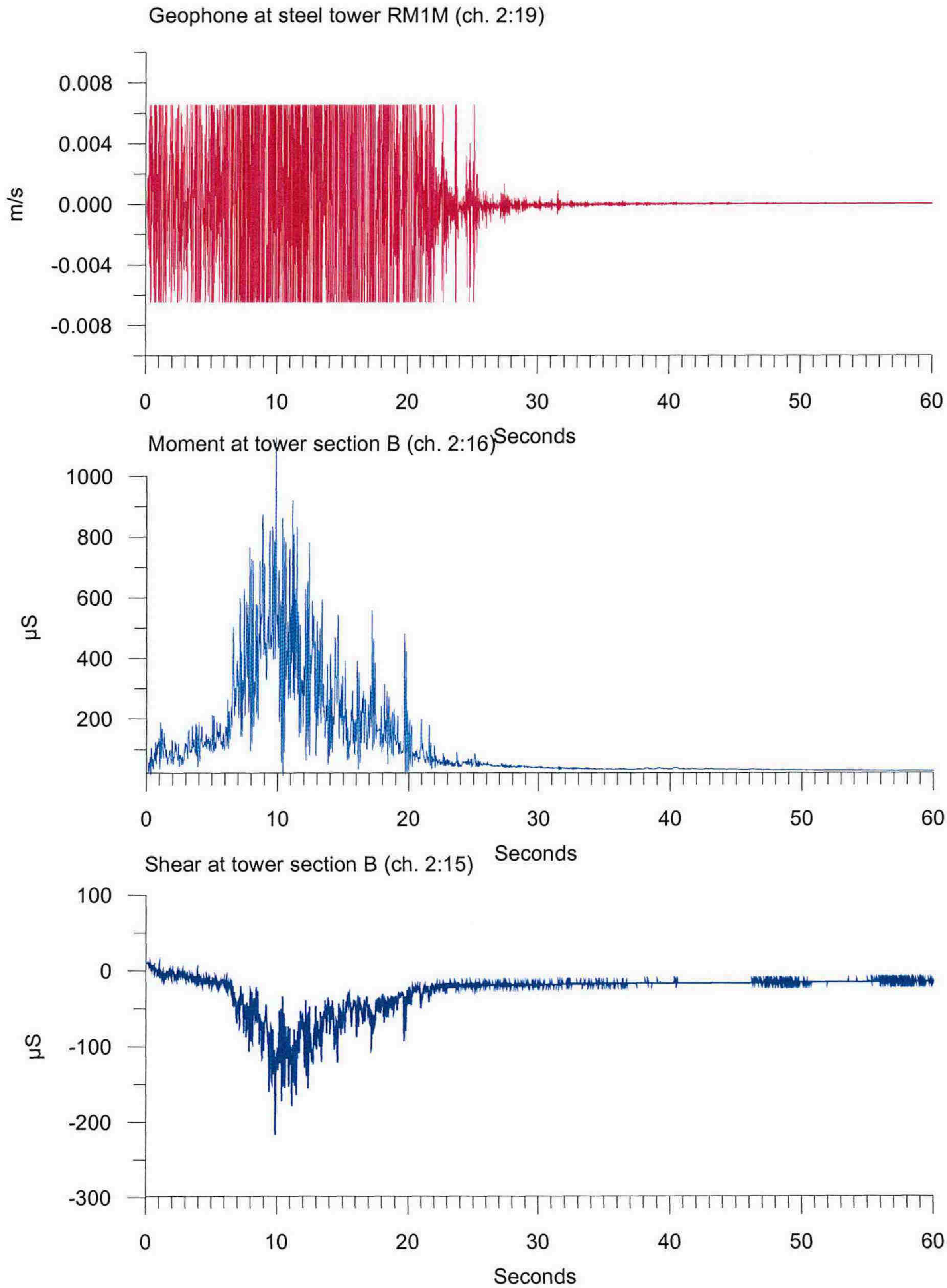
	Revised	
	Approved	NGI



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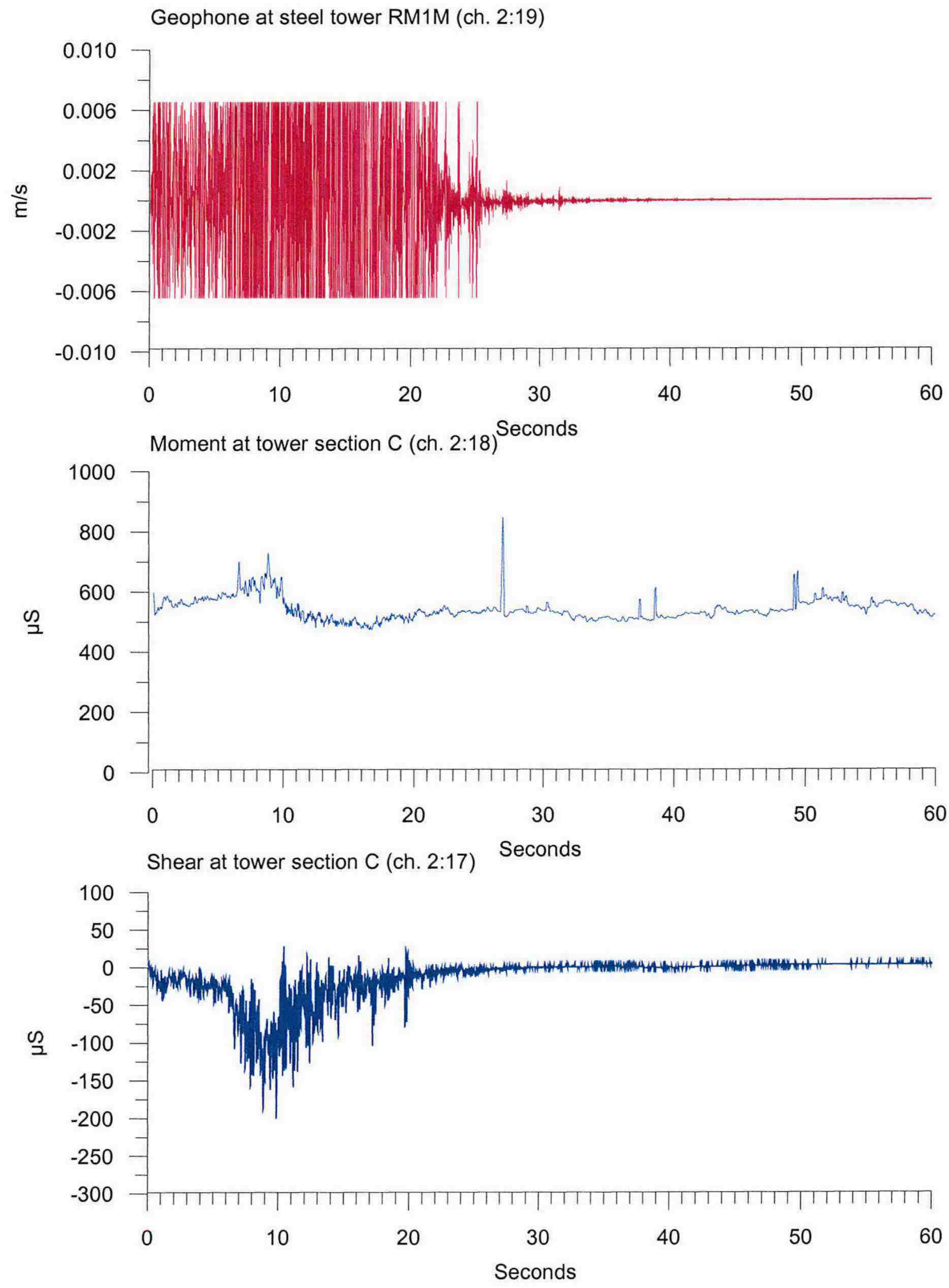
Avalanche 1997-02-07	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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	Revised	NGI
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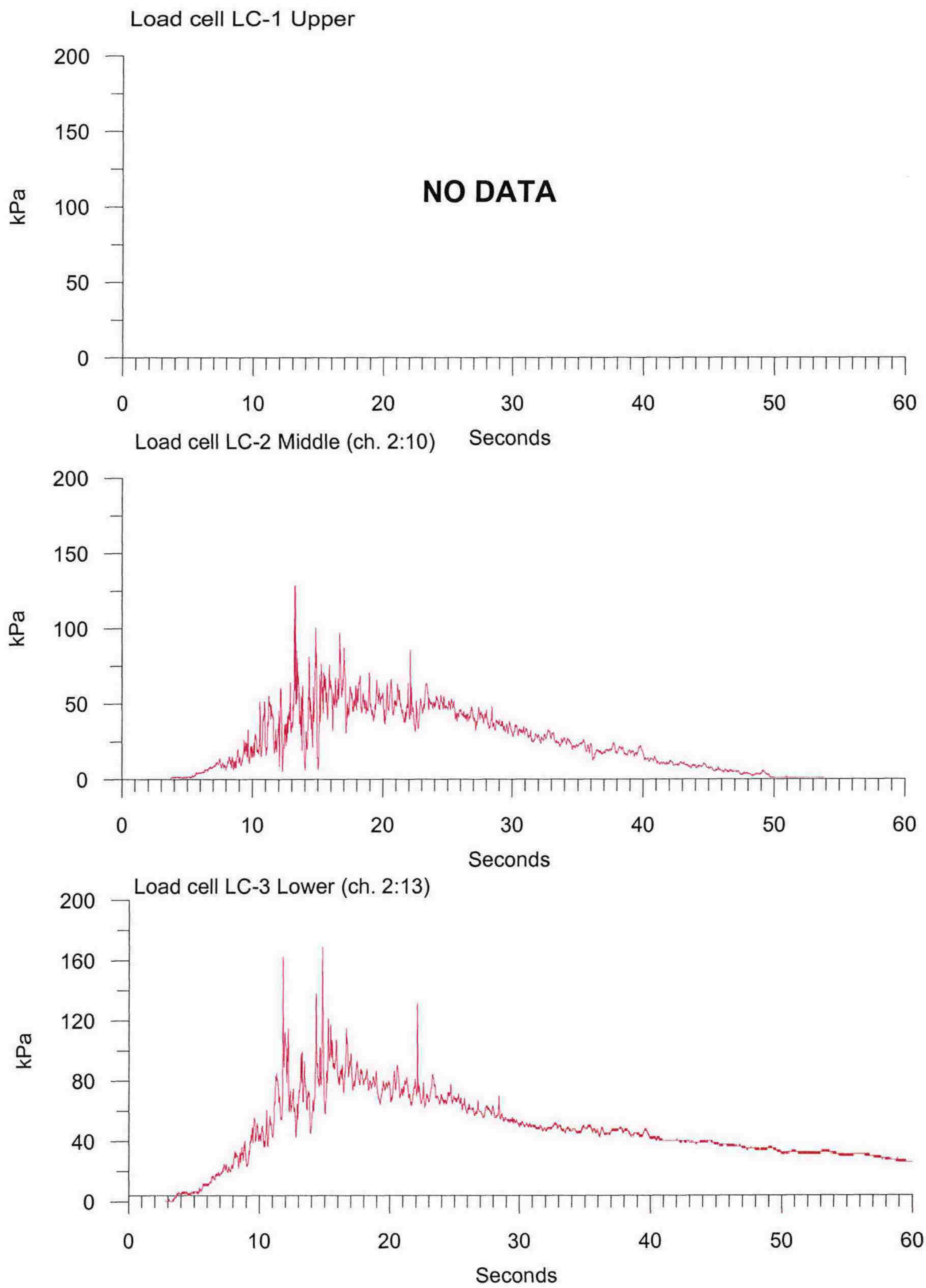

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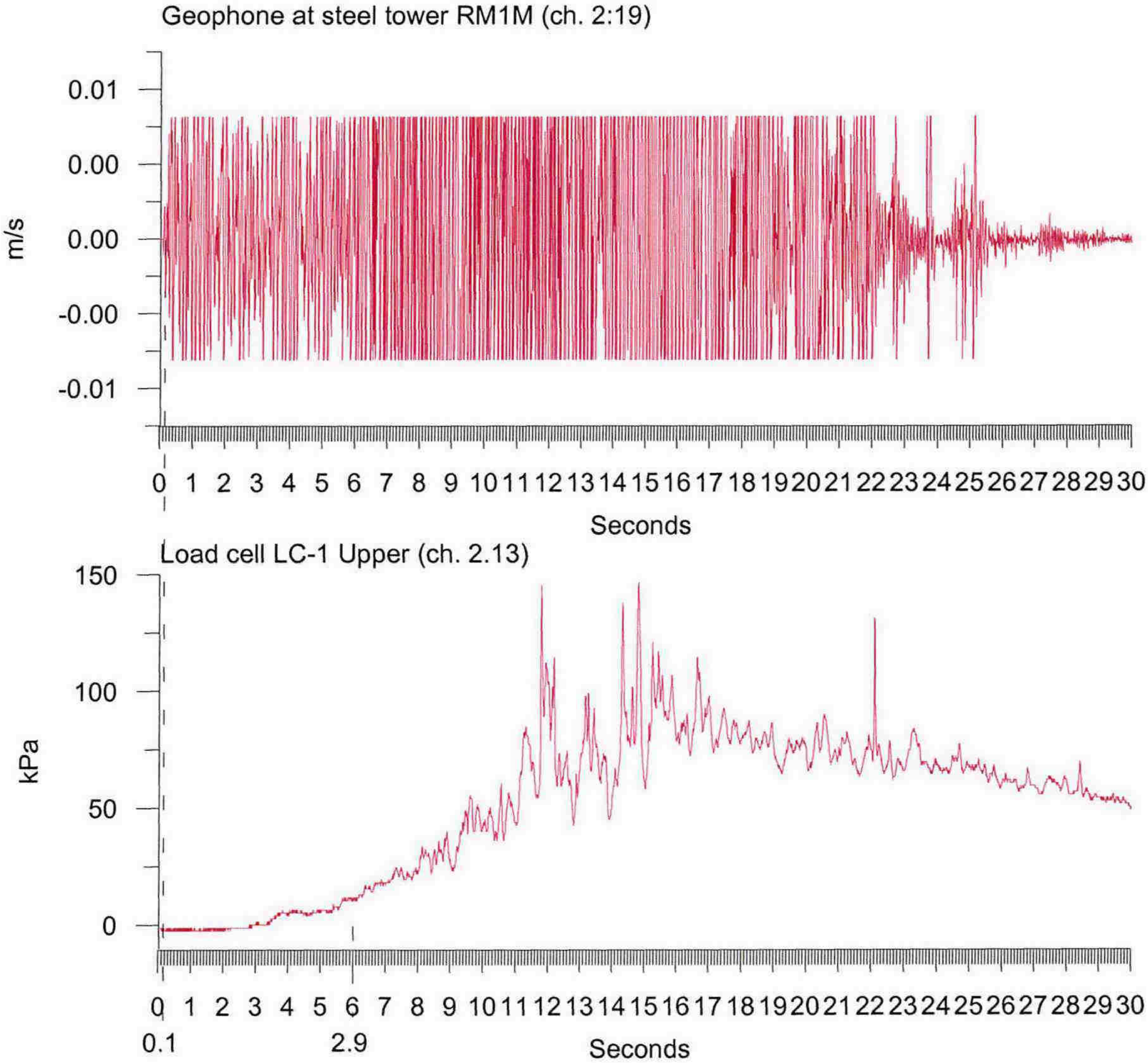

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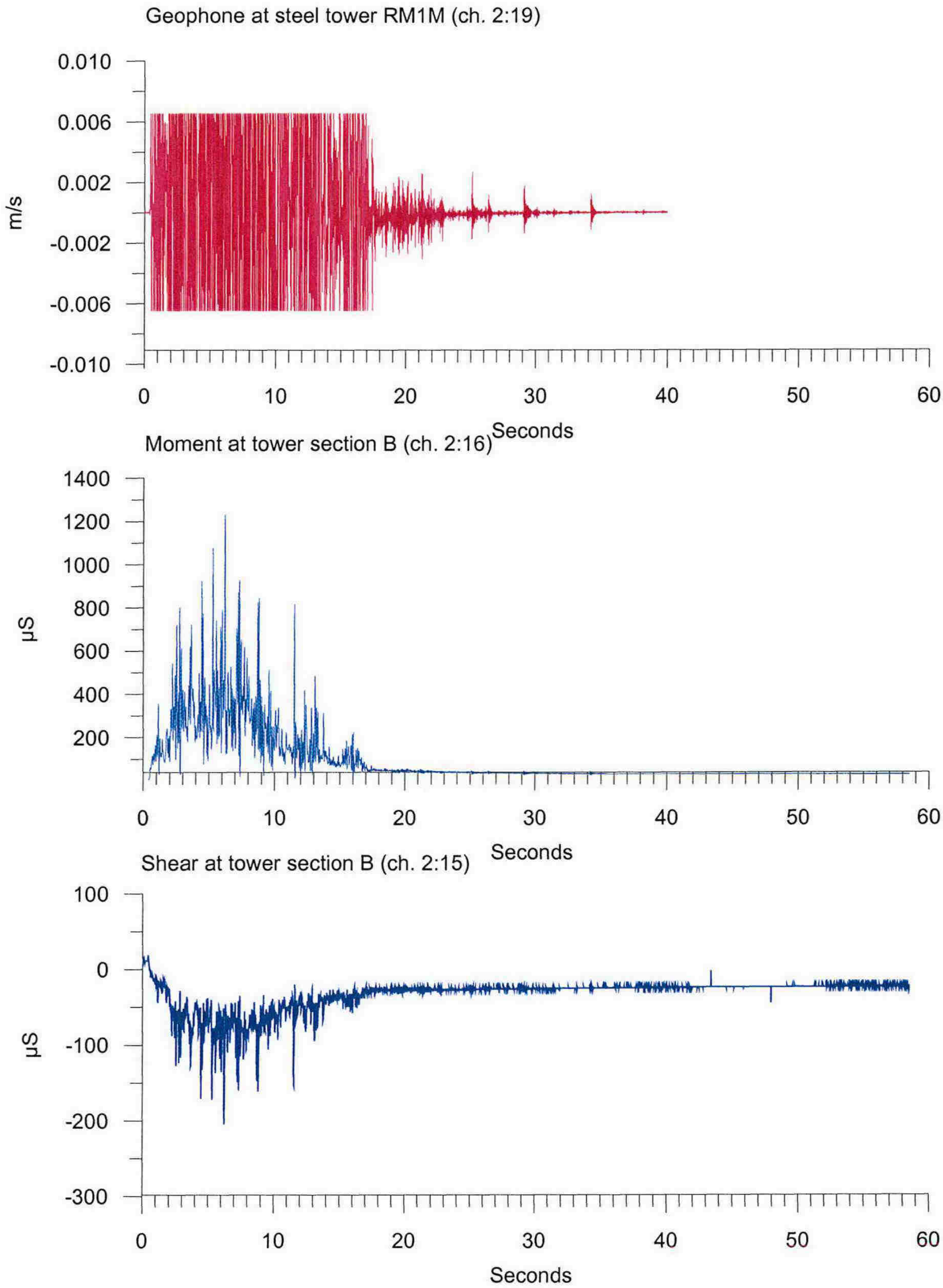
Avalanche 1997-02-07	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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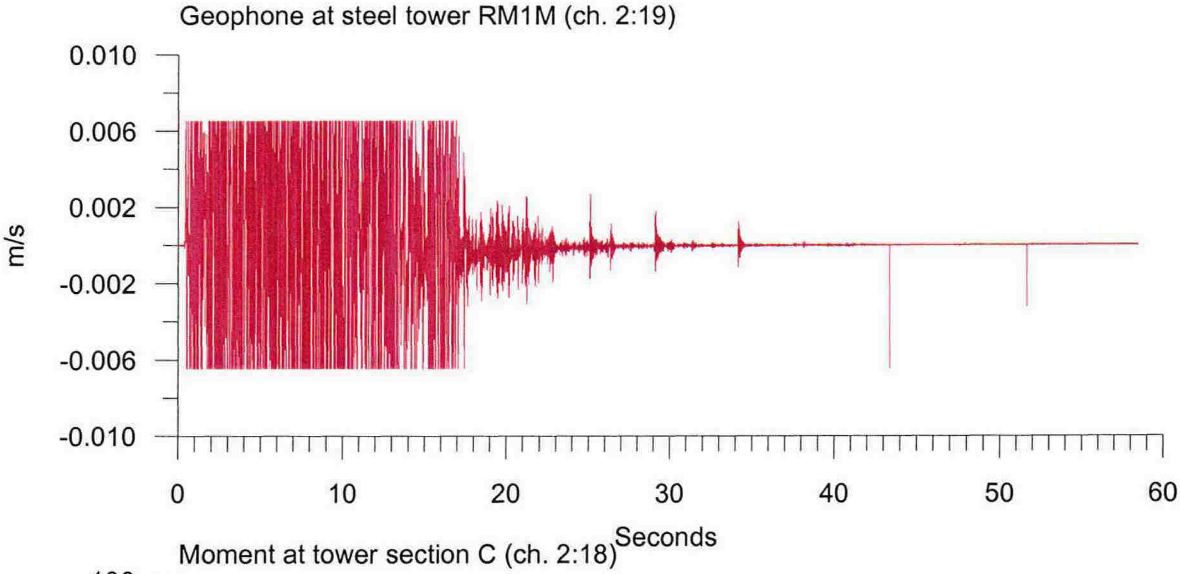
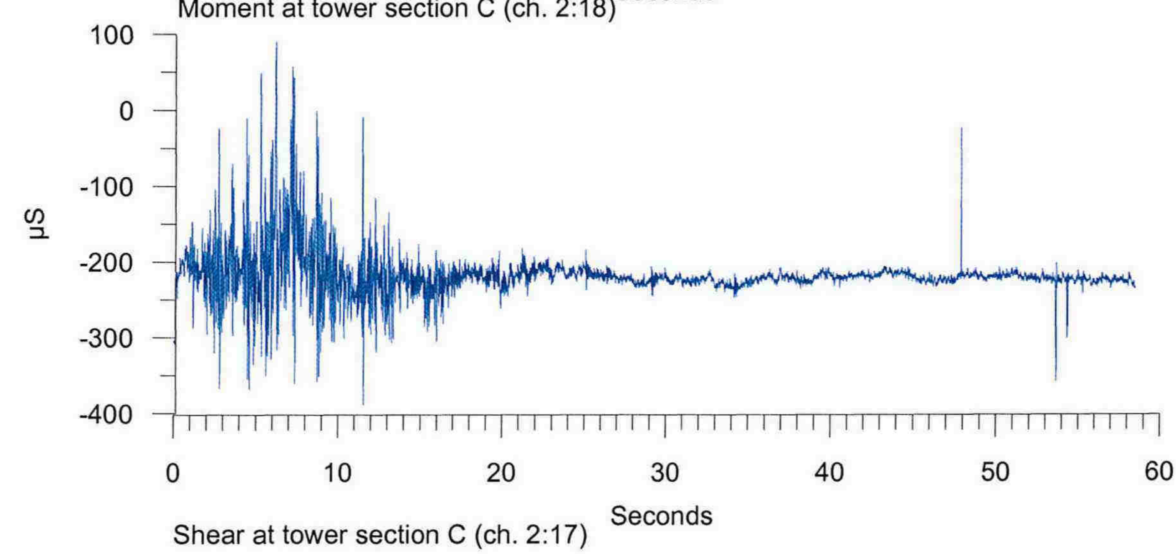
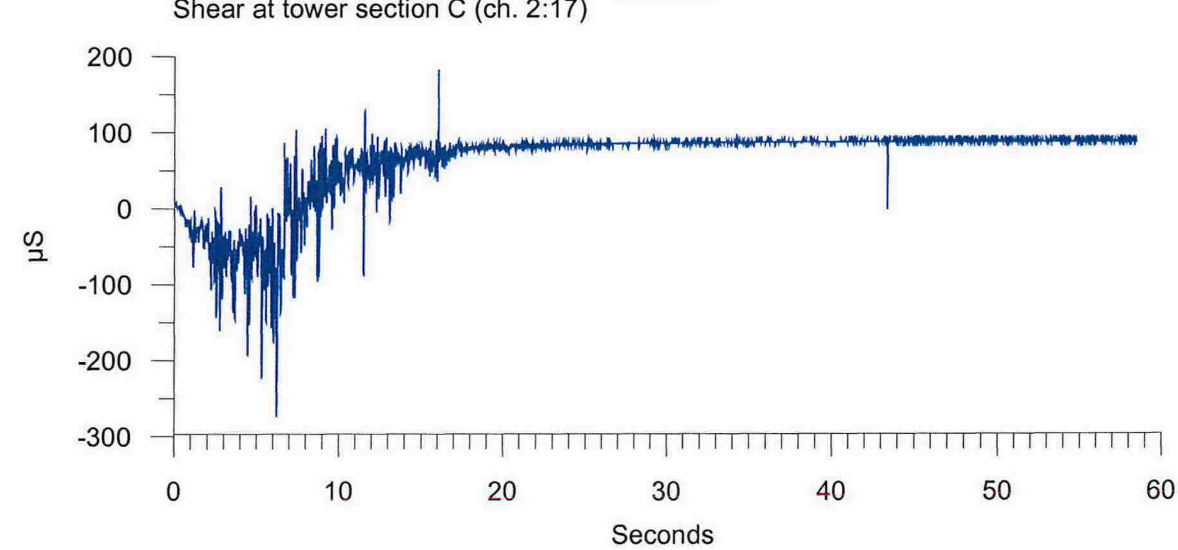
	Approved	







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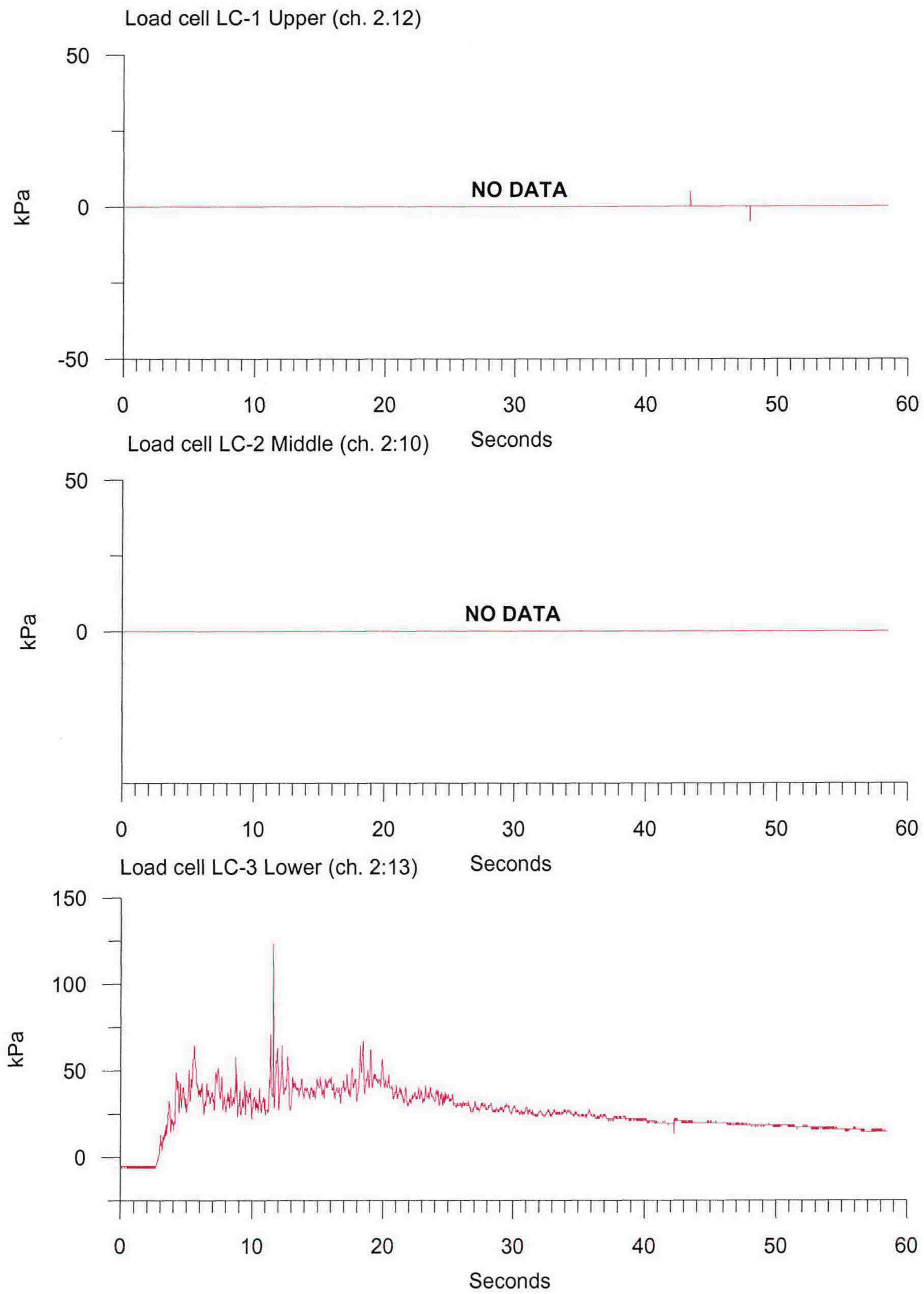
Avalanche 1997-02-08	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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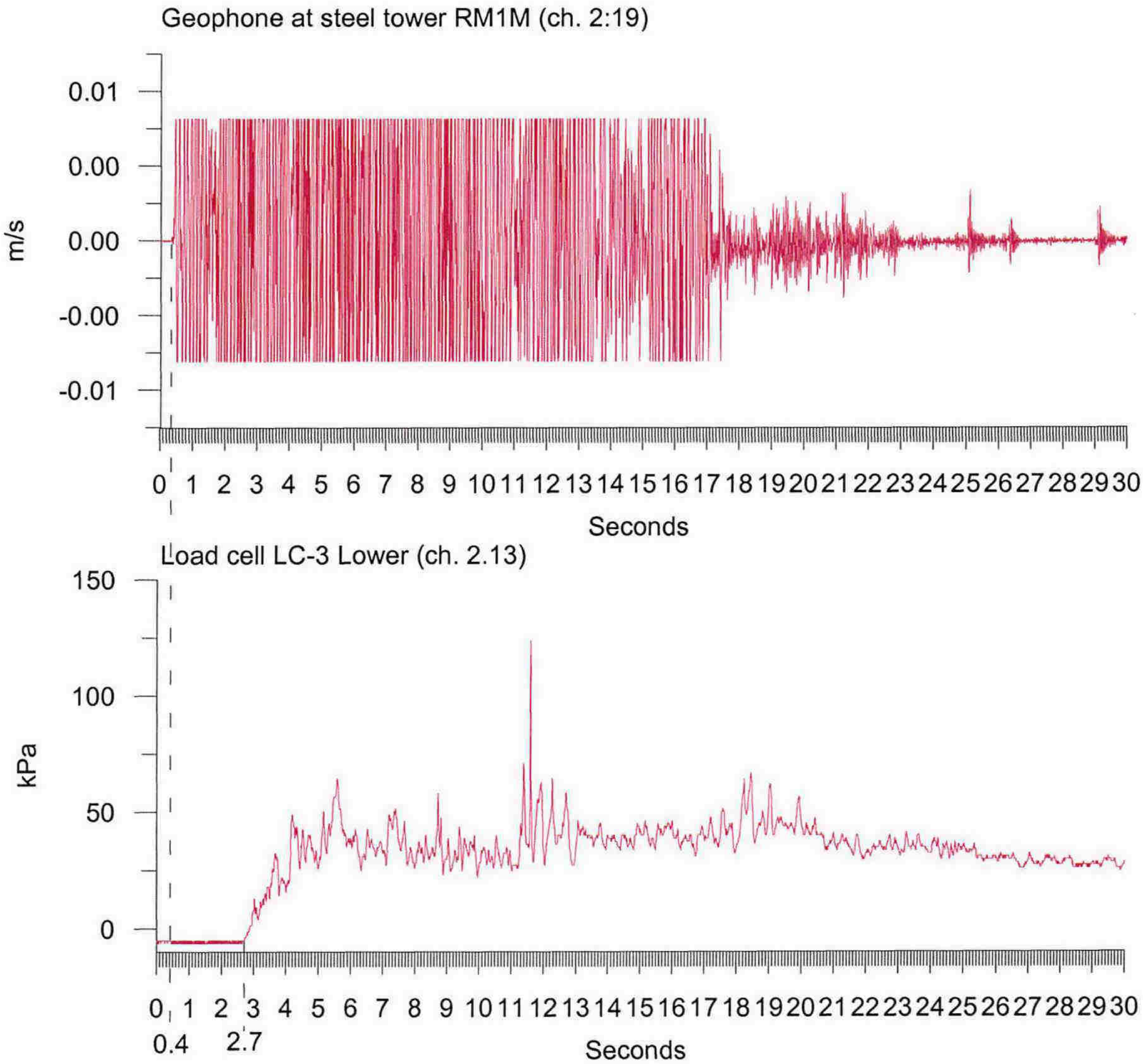

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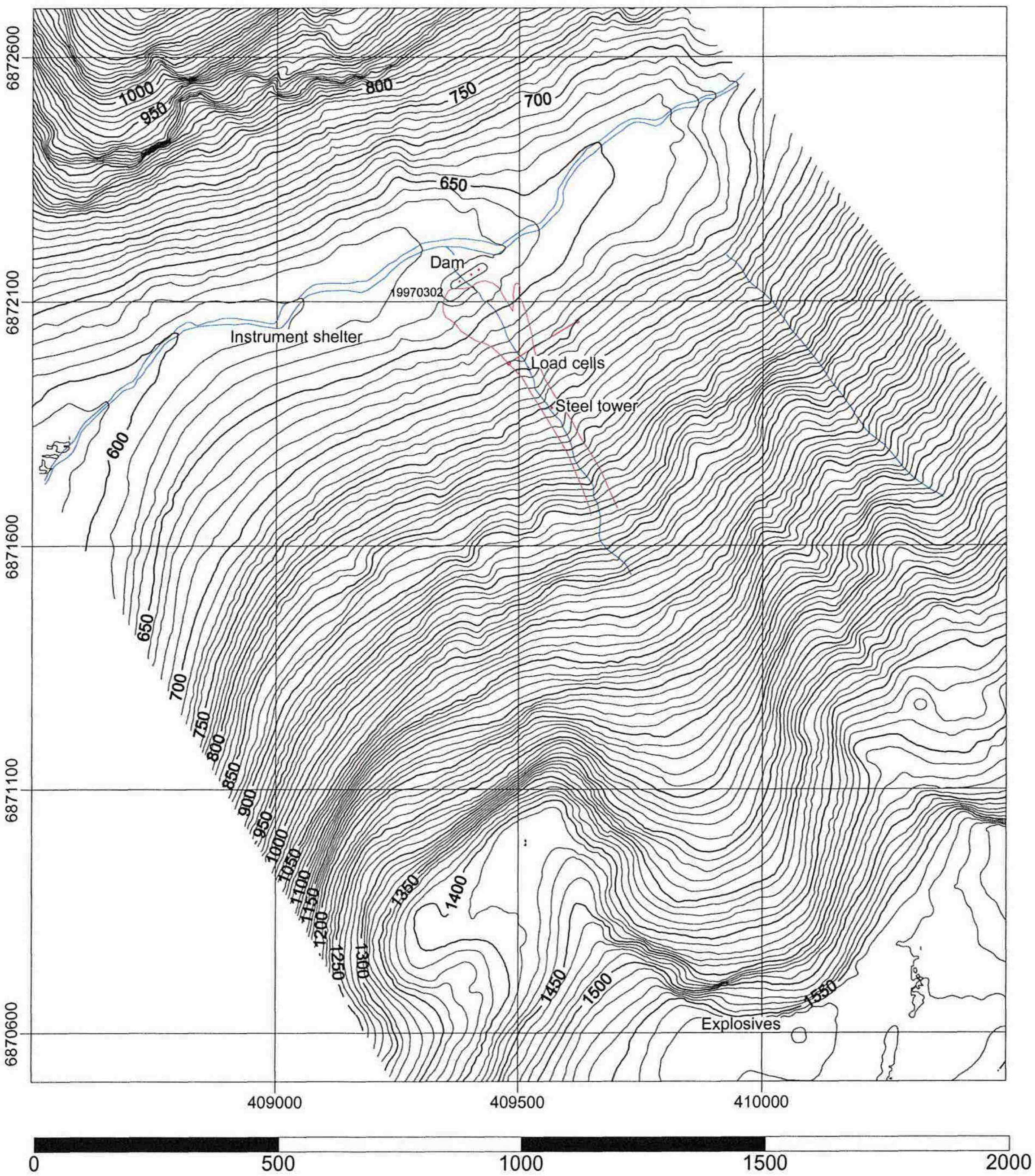
	Approved	



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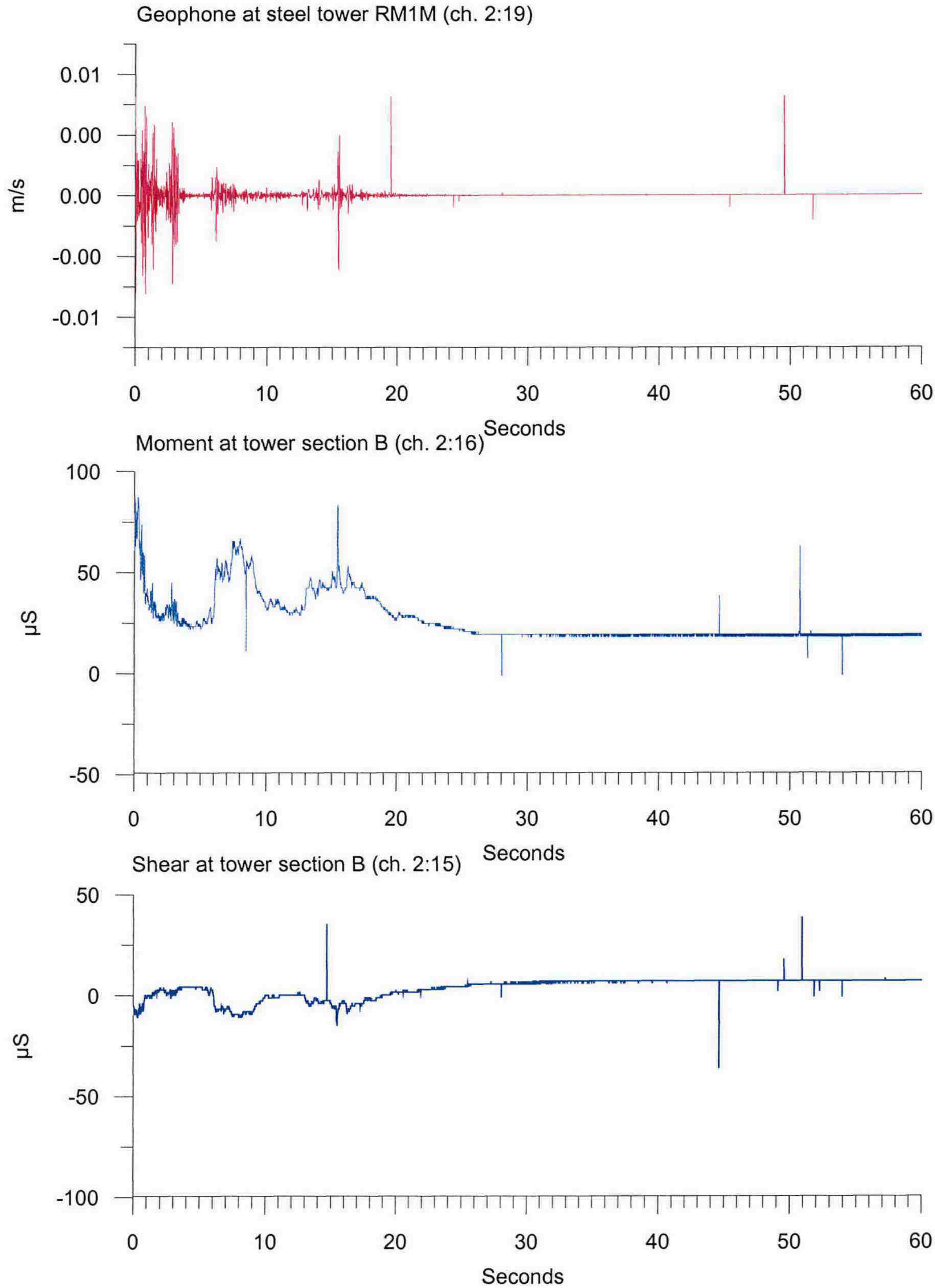
Avalanche 1997-03-02	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



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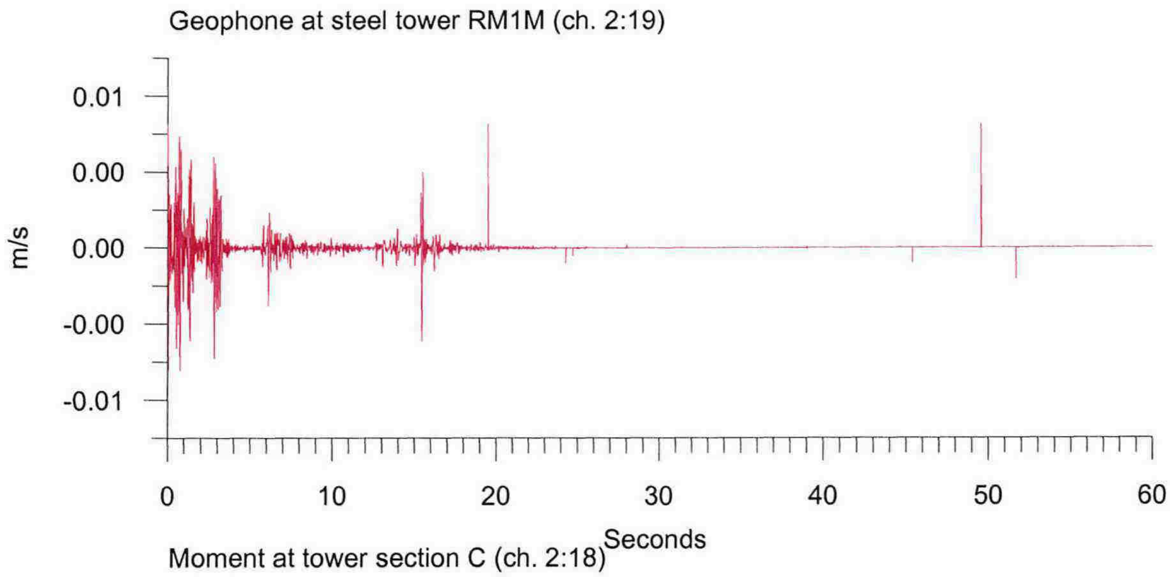
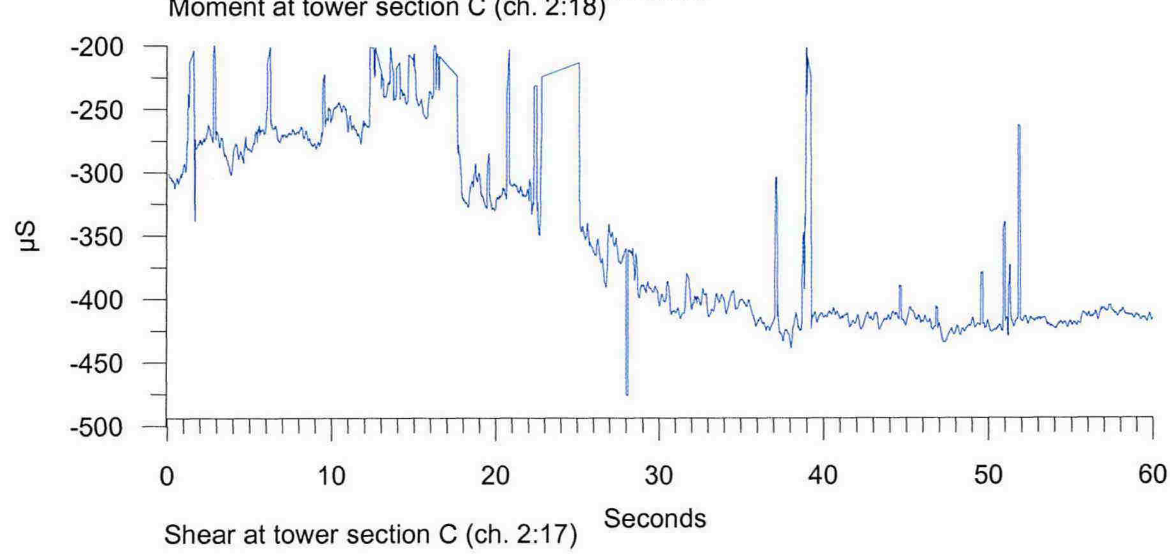
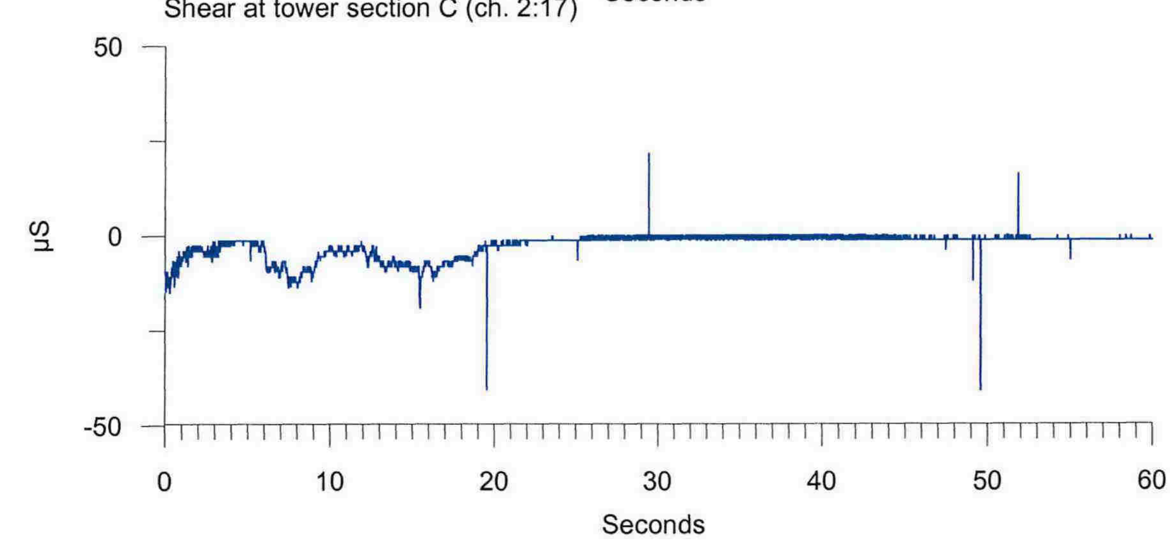
	Revised	NGI
	Approved	







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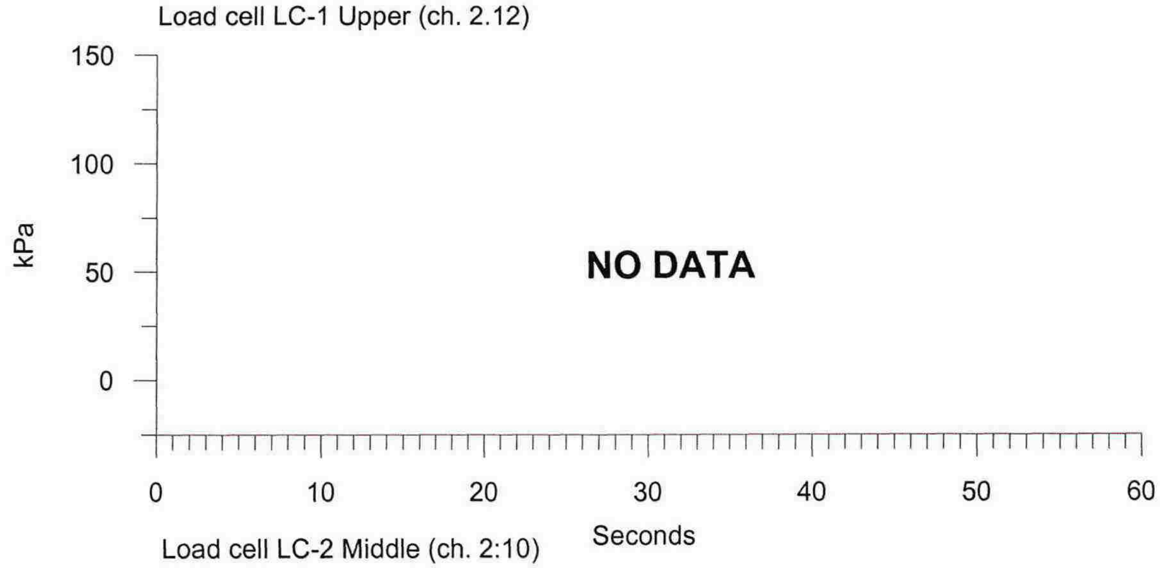
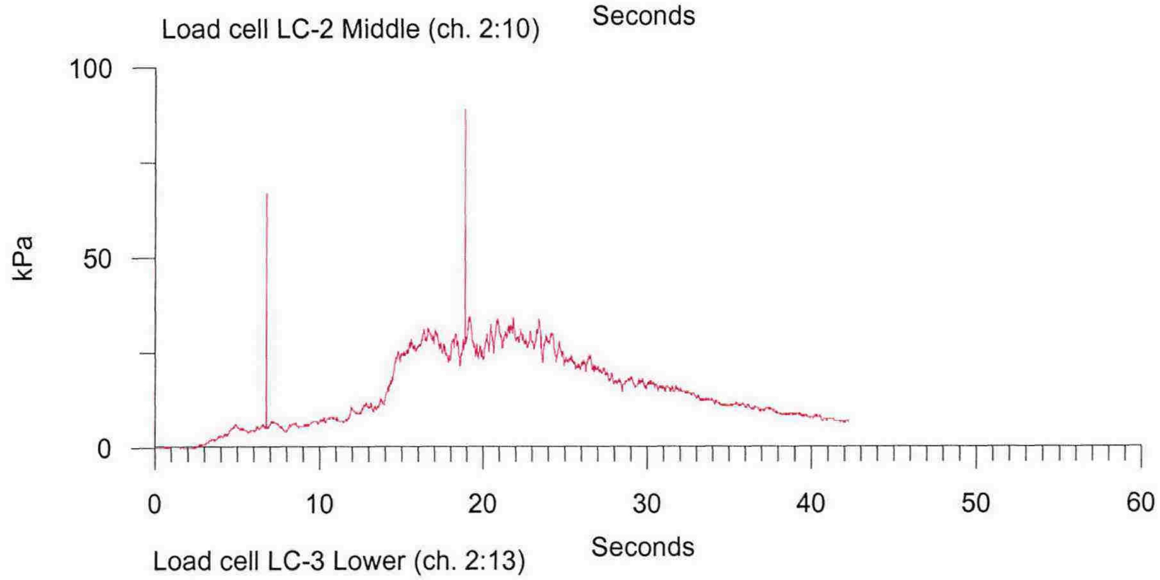
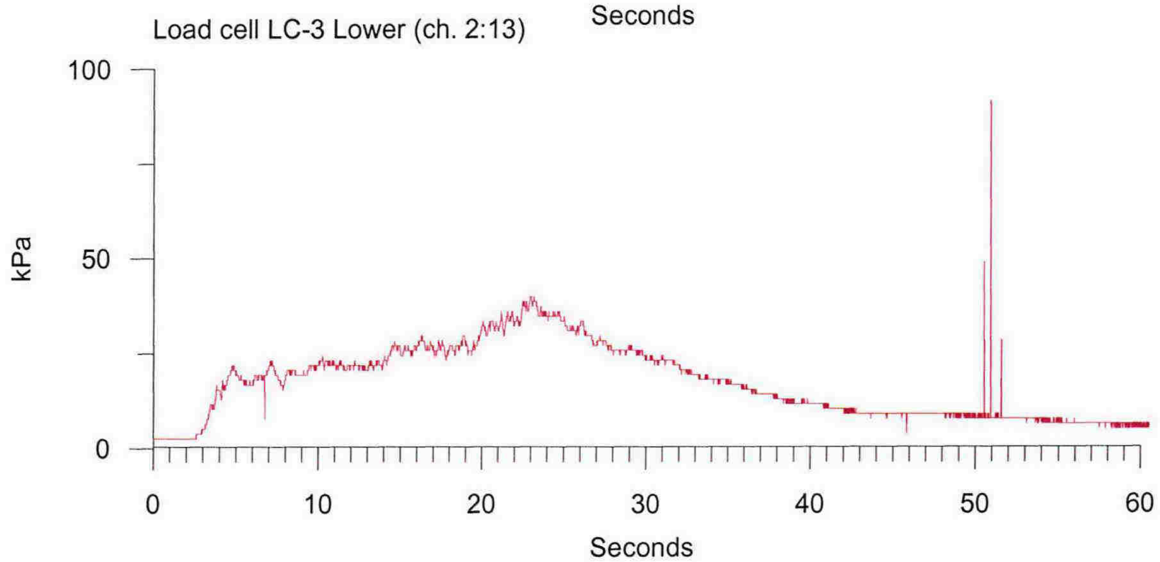
	Revised	
	Approved	NGI







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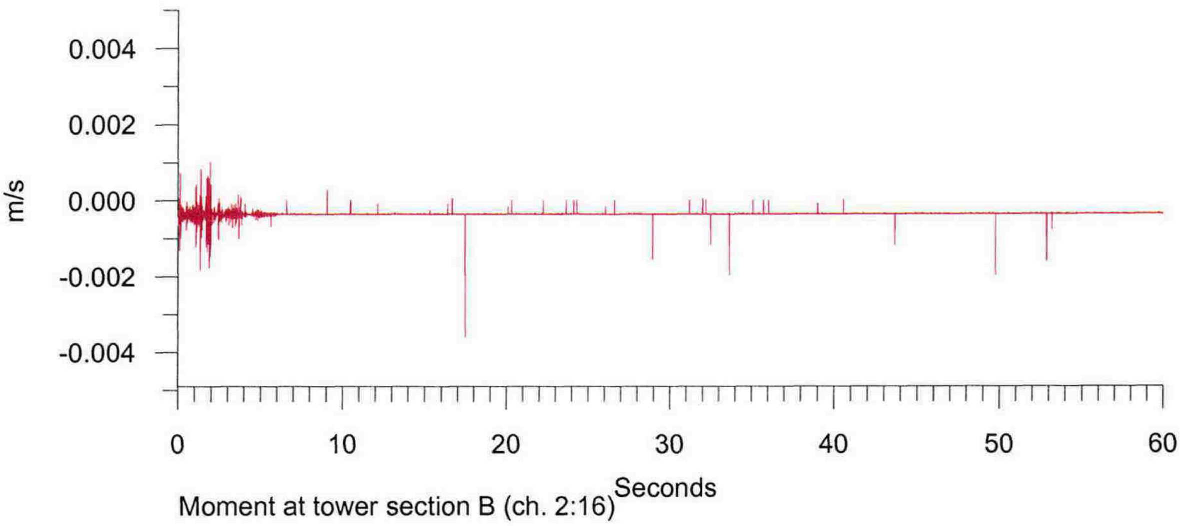
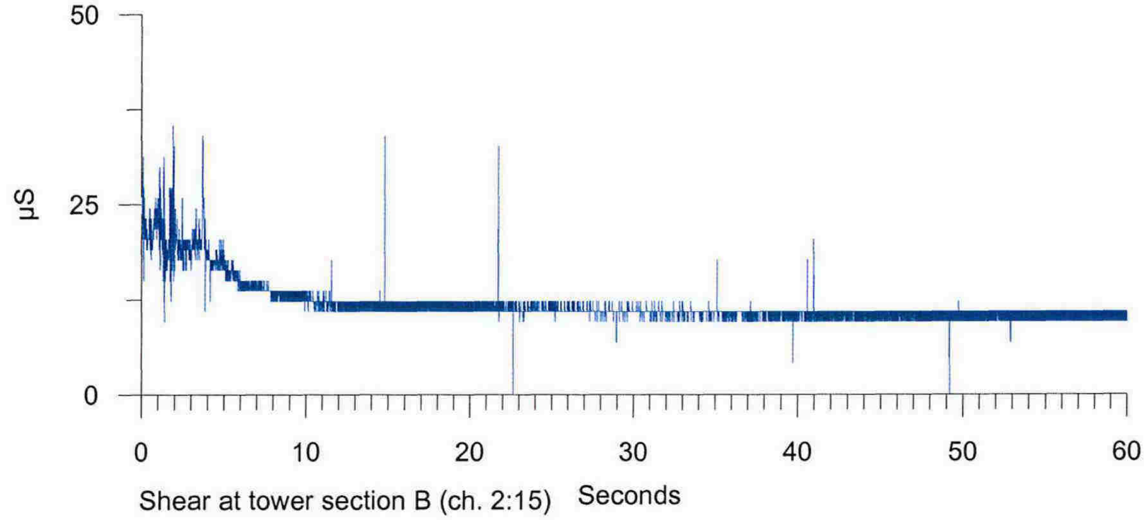
Avalanche 1997-03-02	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

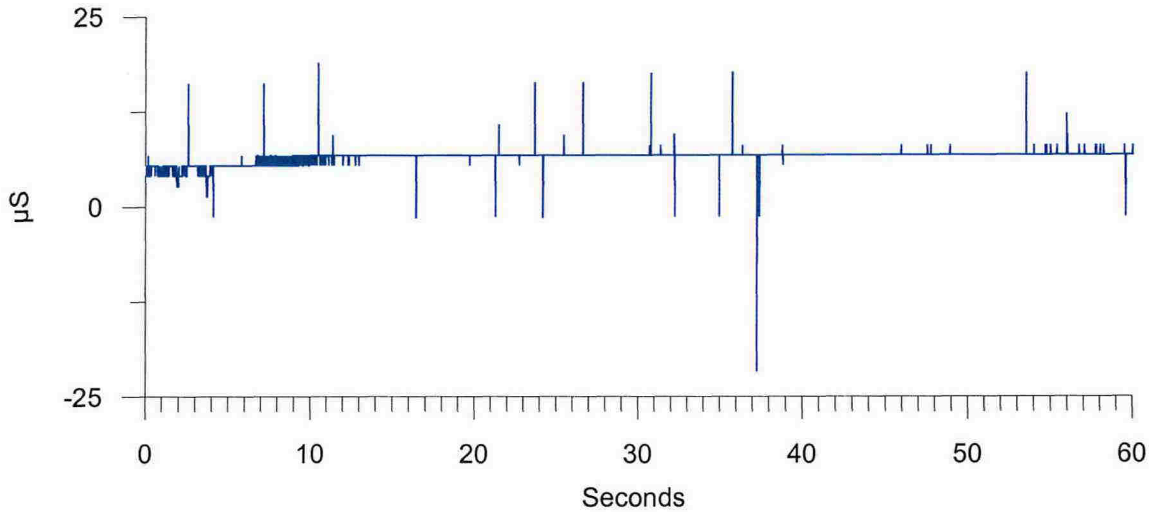
Geophone at steel tower RM1M (ch. 2:19)



Moment at tower section B (ch. 2:16)



Shear at tower section B (ch. 2:15)



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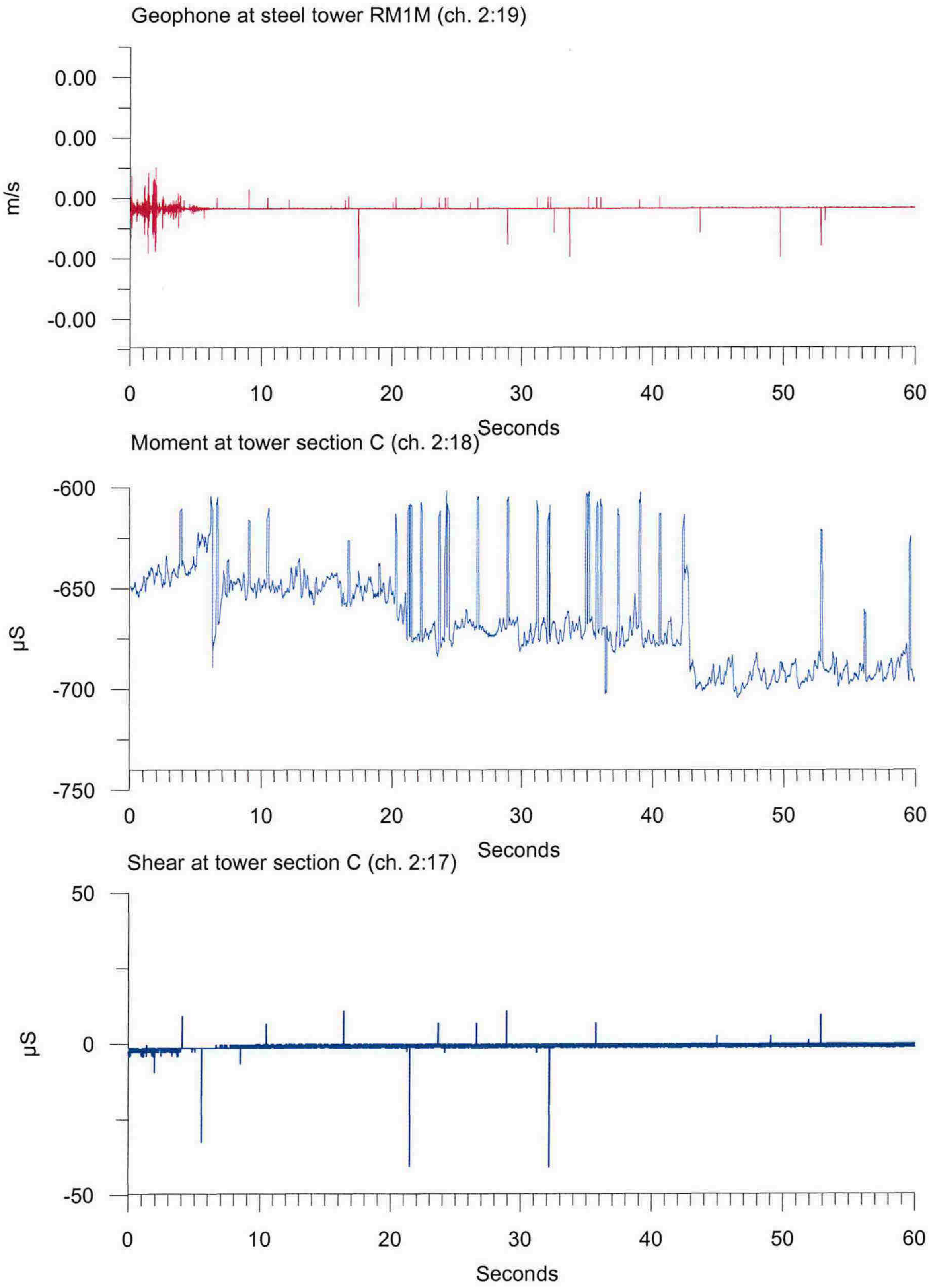
Avalanche 1997-03-28	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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Avalanche 1997-03-28	Drawn by KKr	Date 2001-11-01
	Revised	NGI
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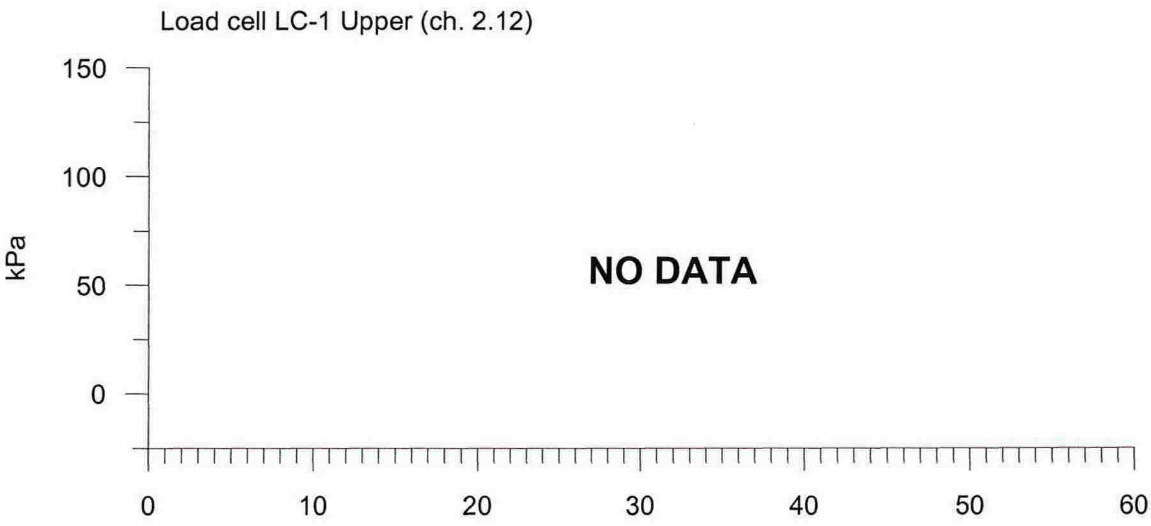

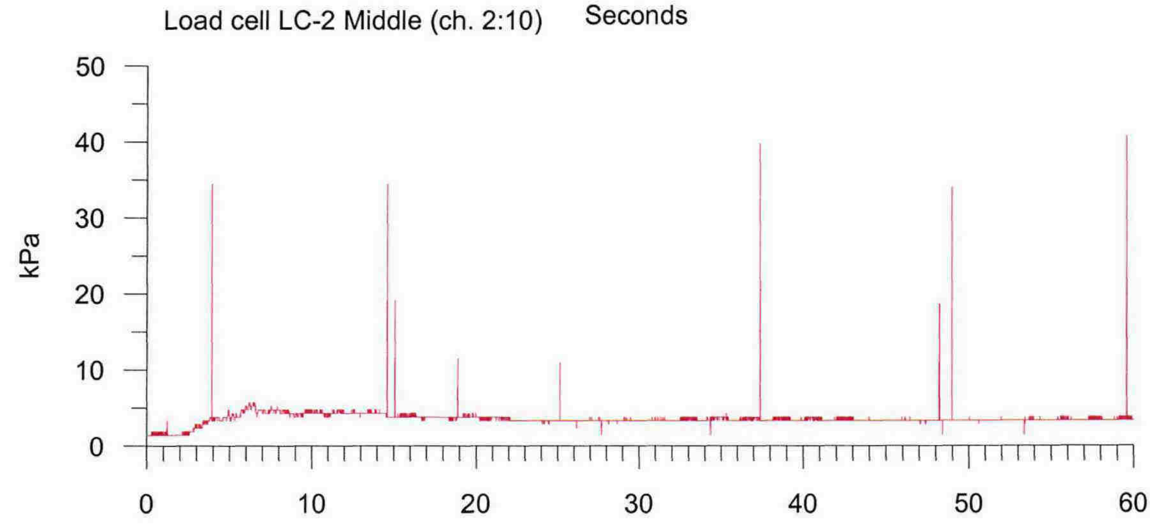

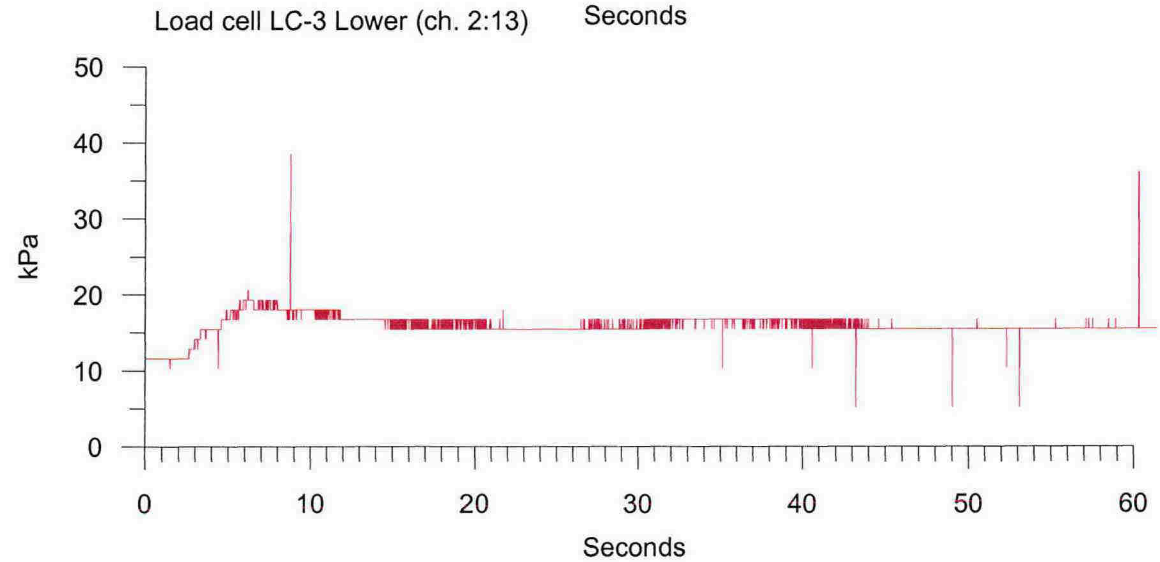

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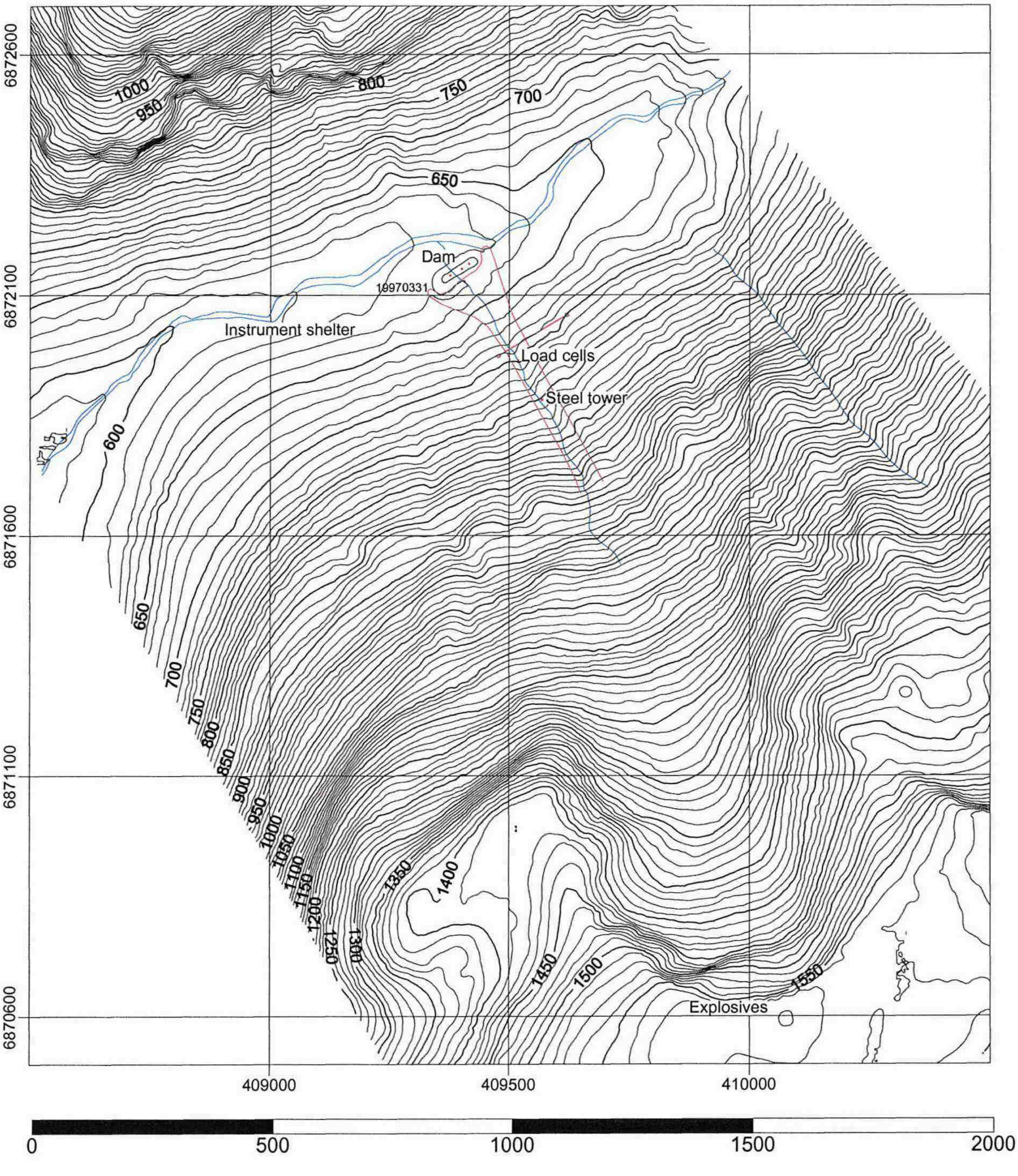
Avalanche 1997-03-28	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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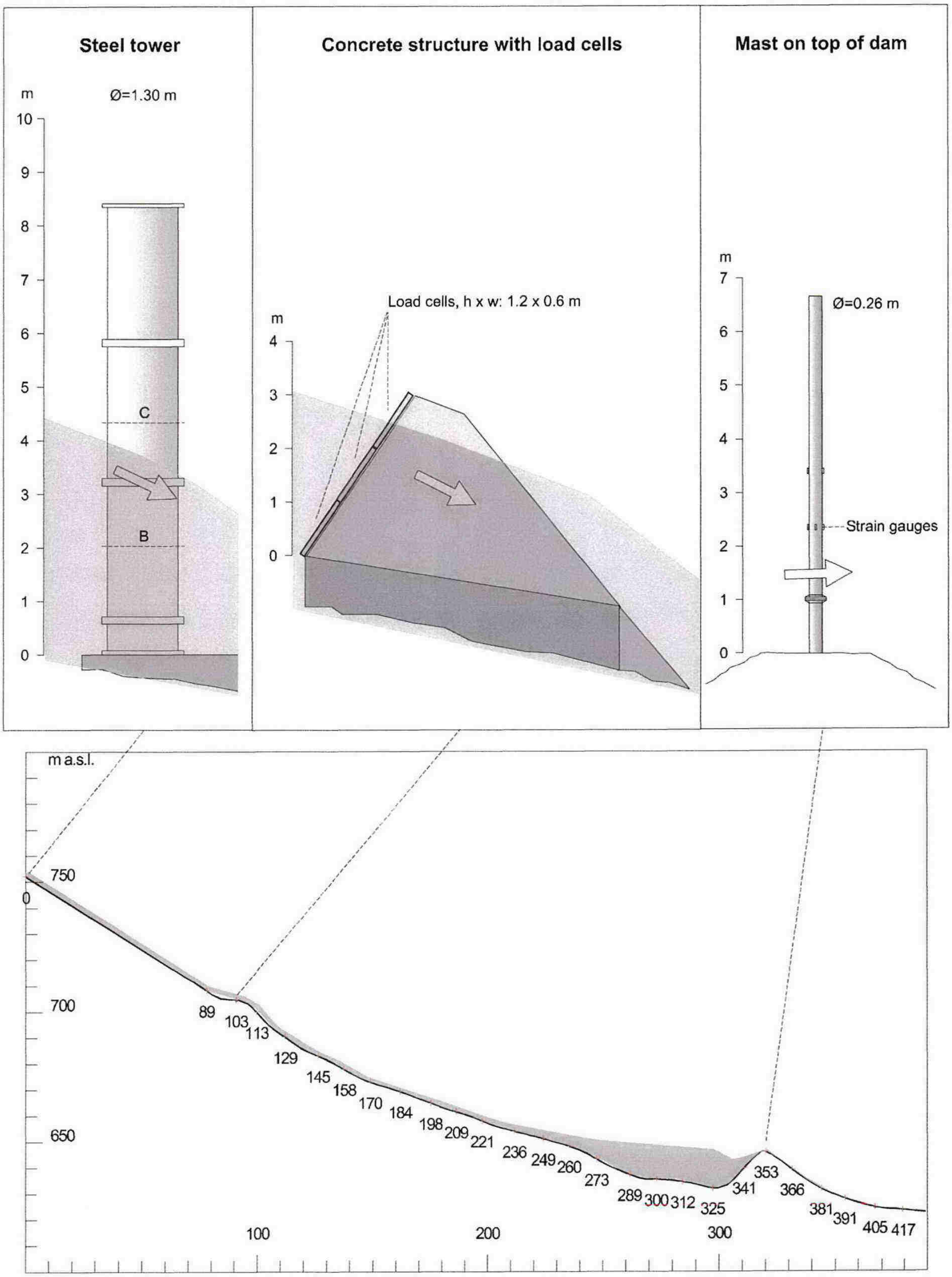
Avalanches 1997-03-31	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



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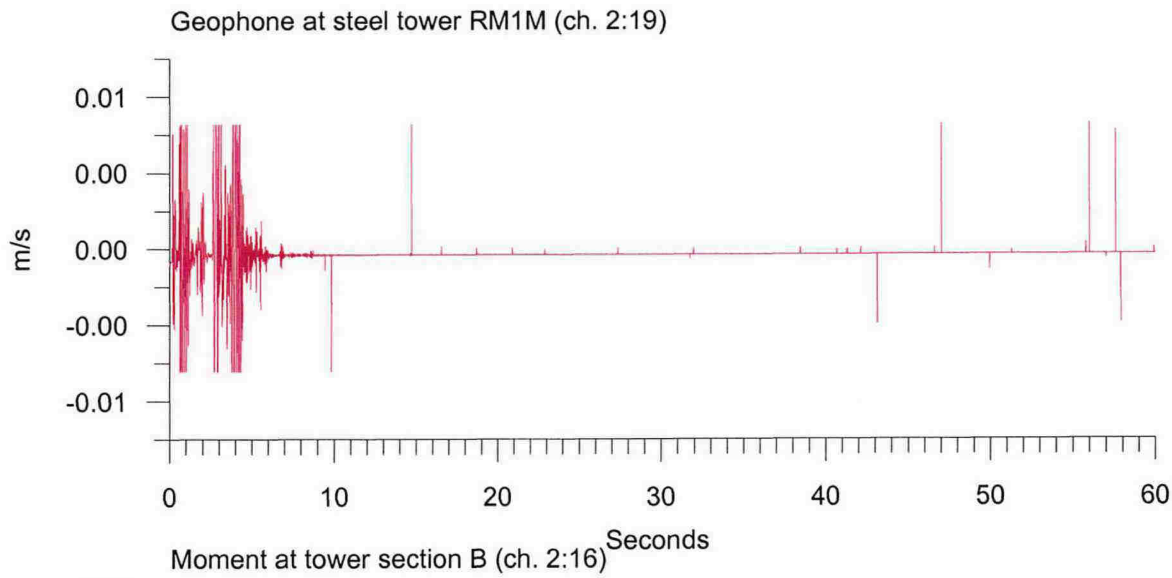
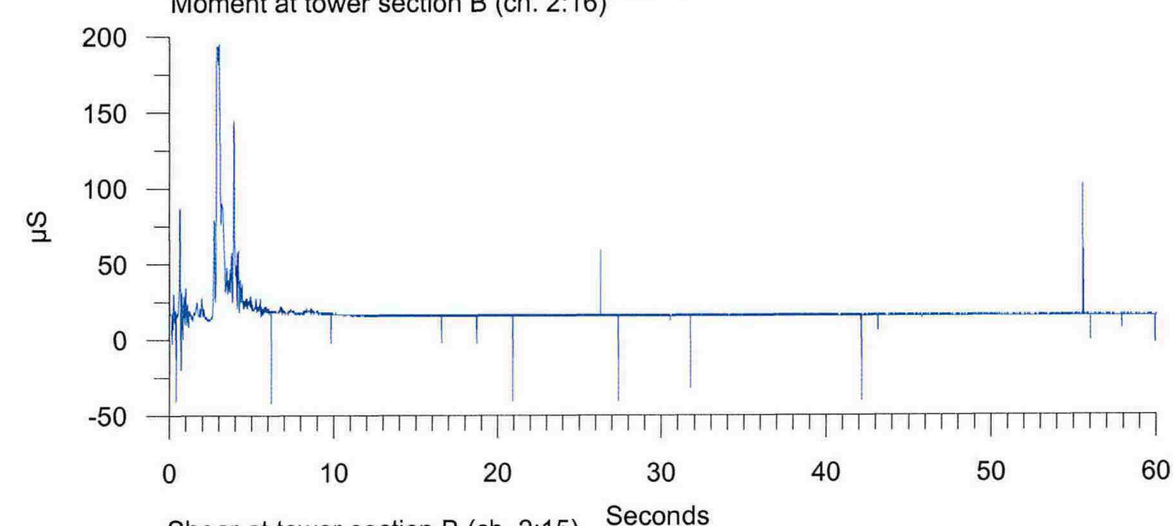
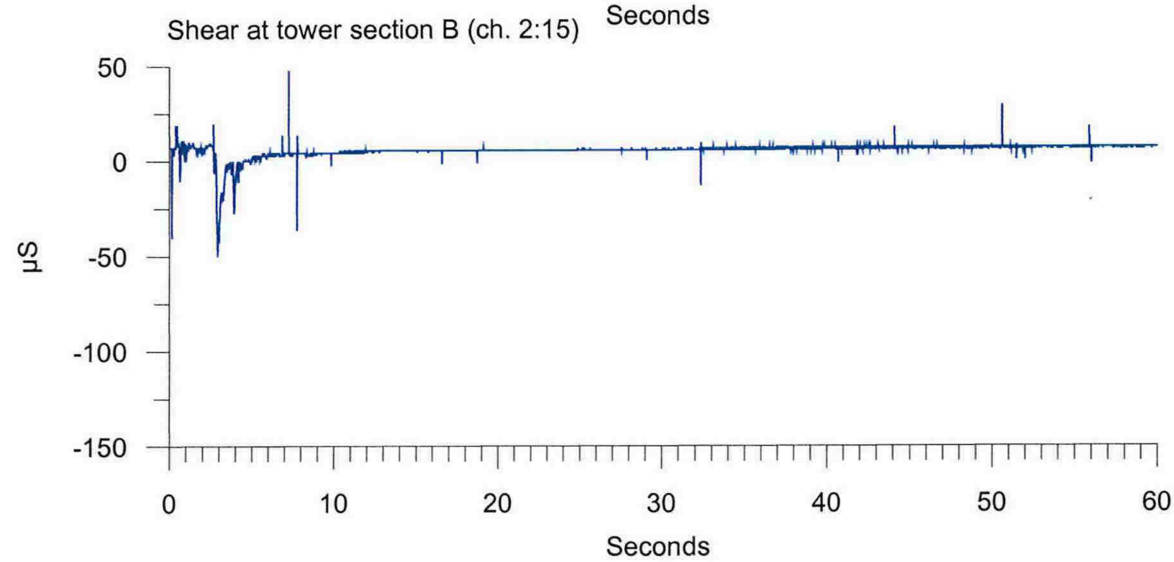
Avalanches 1997-03-31 Distribution of avlanche debris around the constructions, observed 03-31	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI







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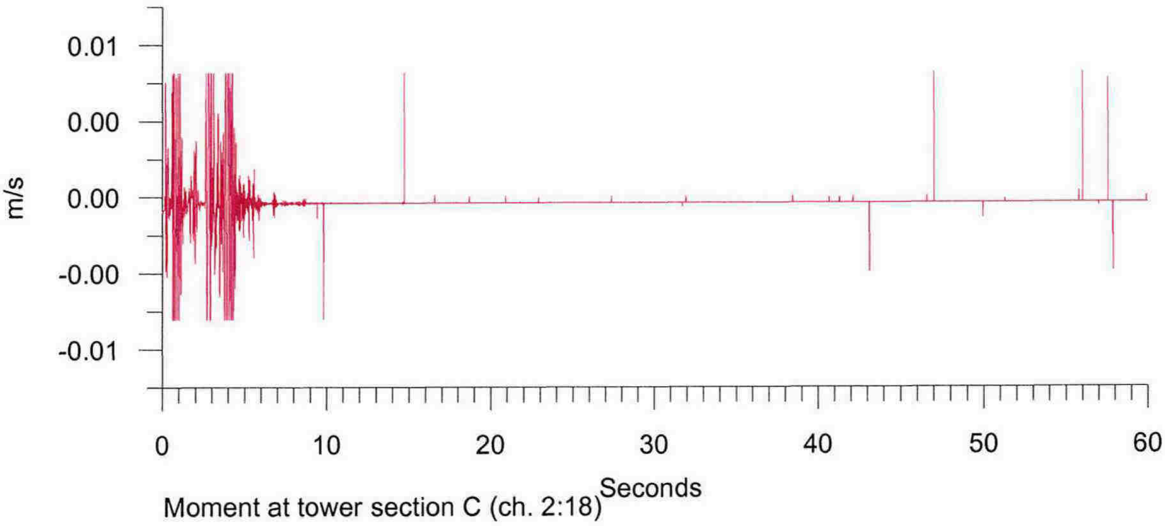
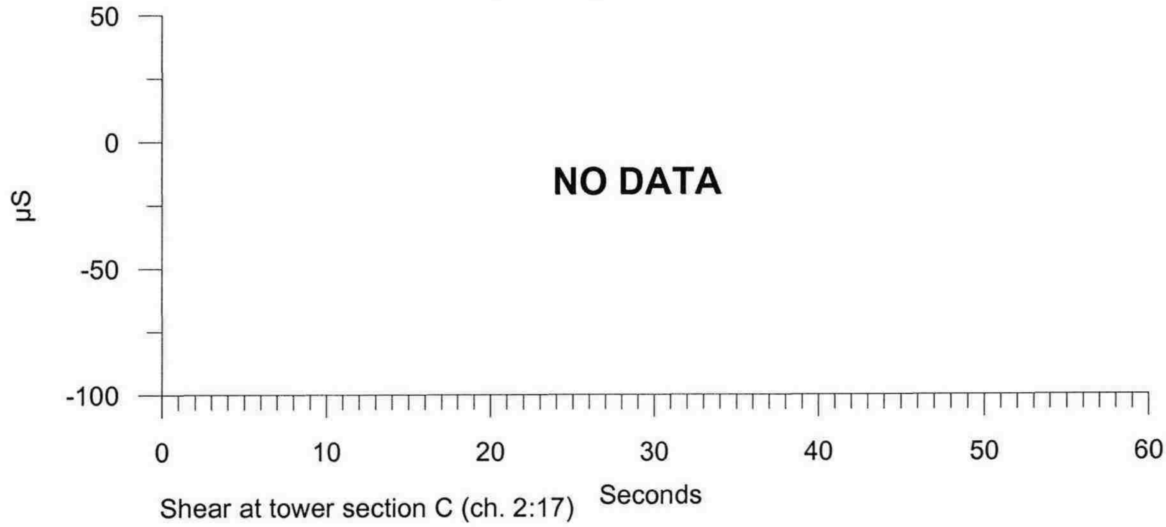
Avalanche 1997-03-31 0:44		Drawn by KKr	Date 2001-11-01
		Revised	NGI
		Approved	

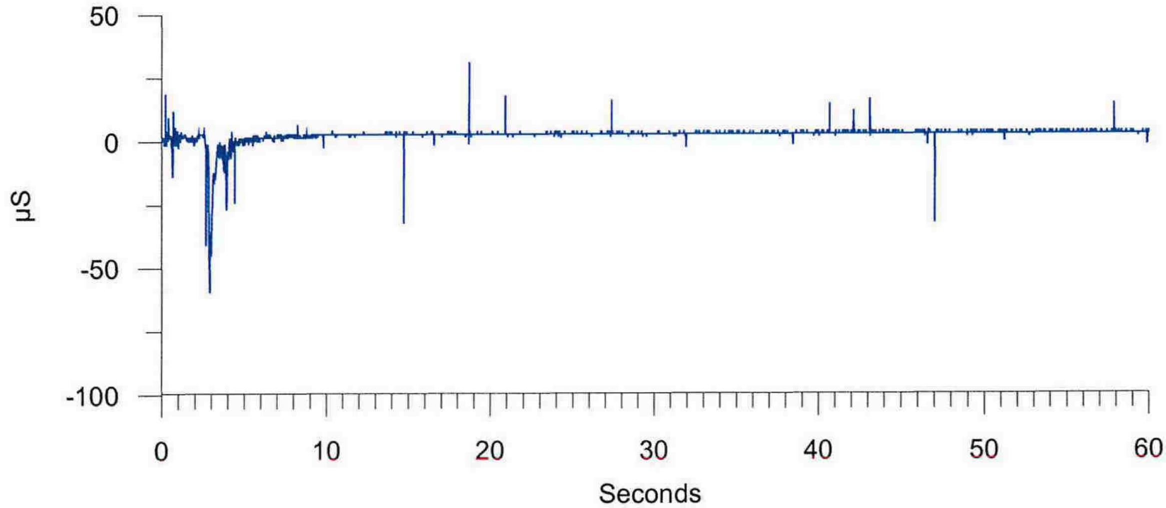
Geophone at steel tower RM1M (ch. 2:19)



Moment at tower section C (ch. 2:18)



Shear at tower section C (ch. 2:17)



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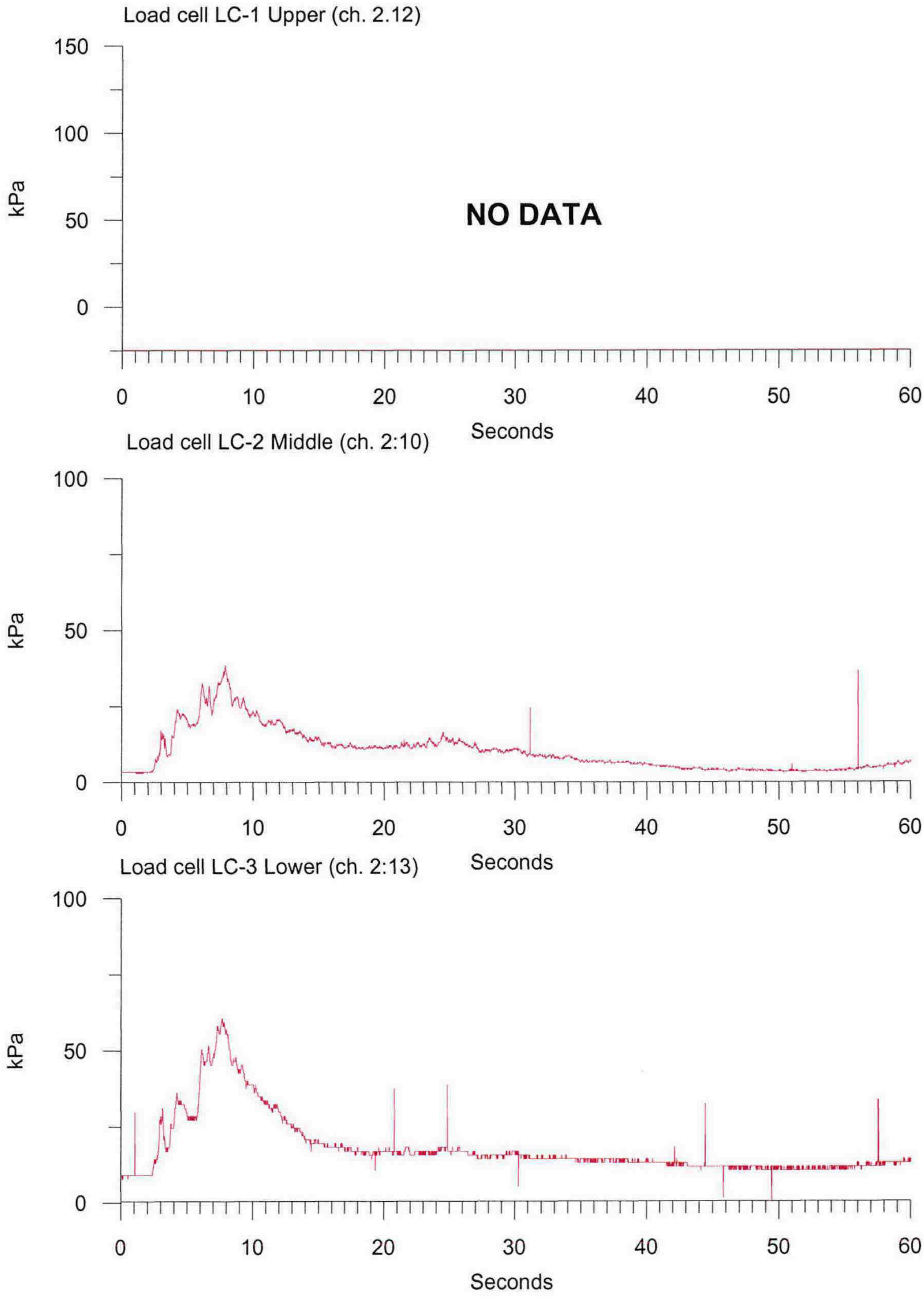
	Revised	NGI
	Approved *al*	



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	Revised	
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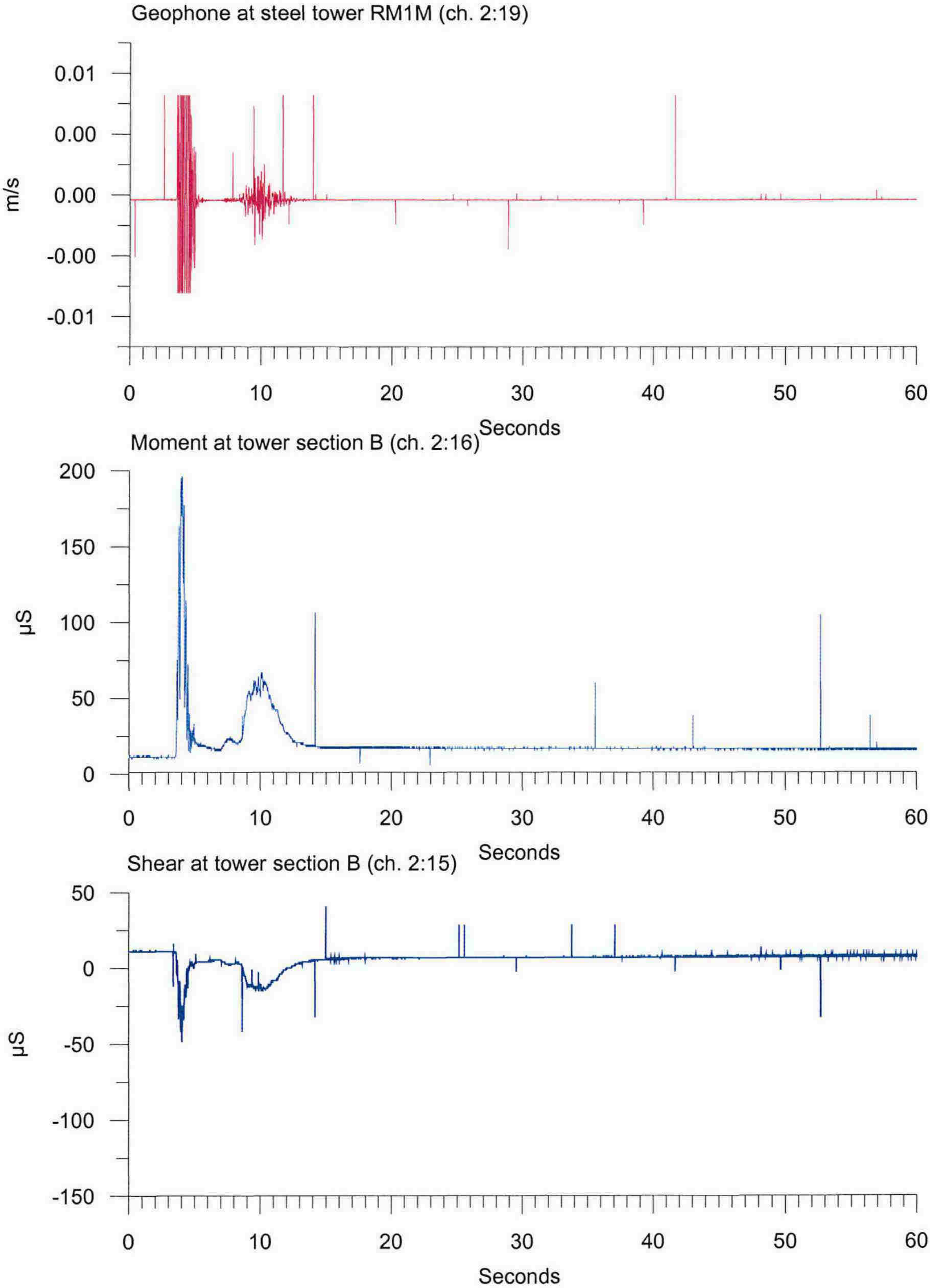

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	Revised	
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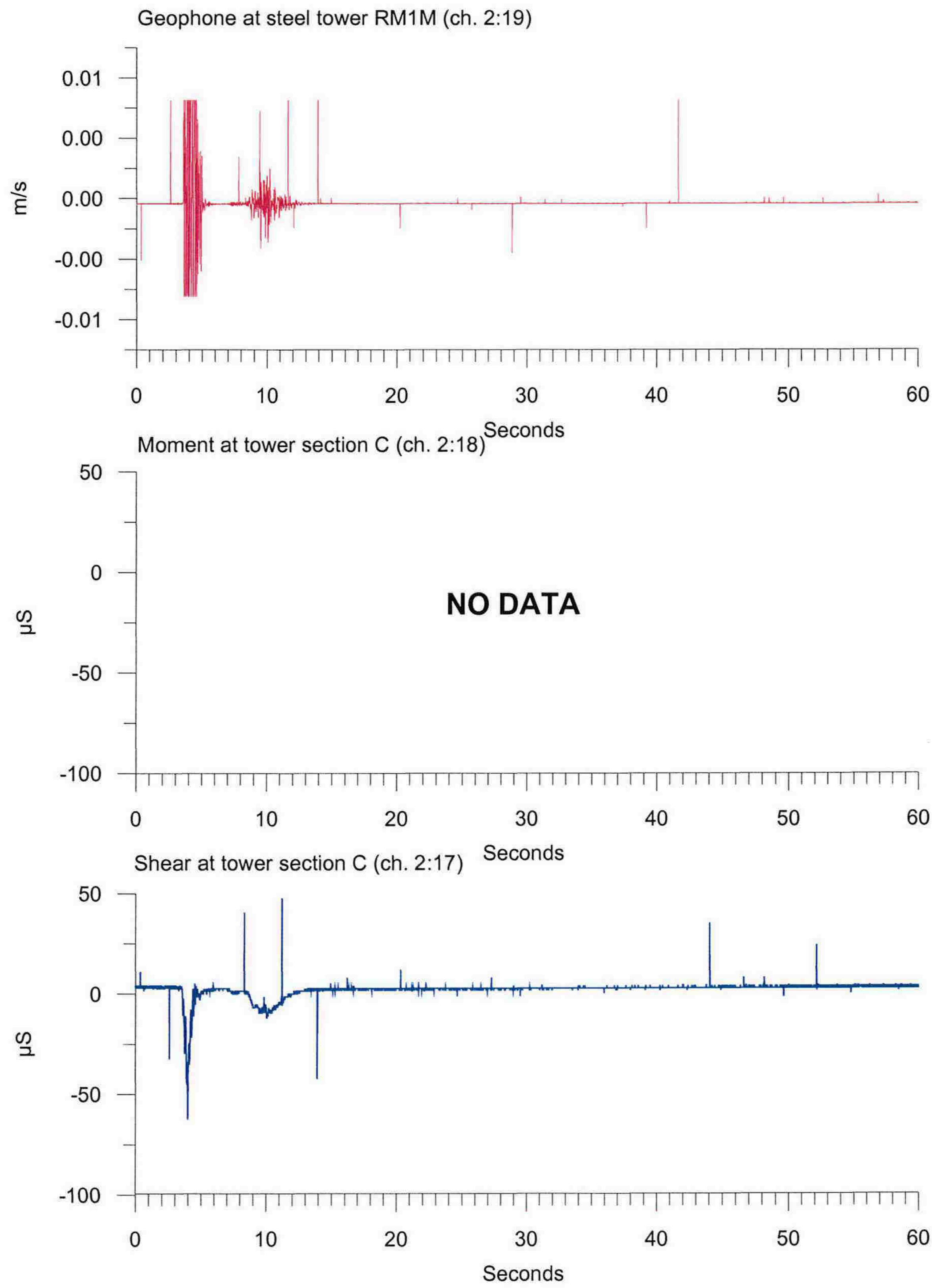

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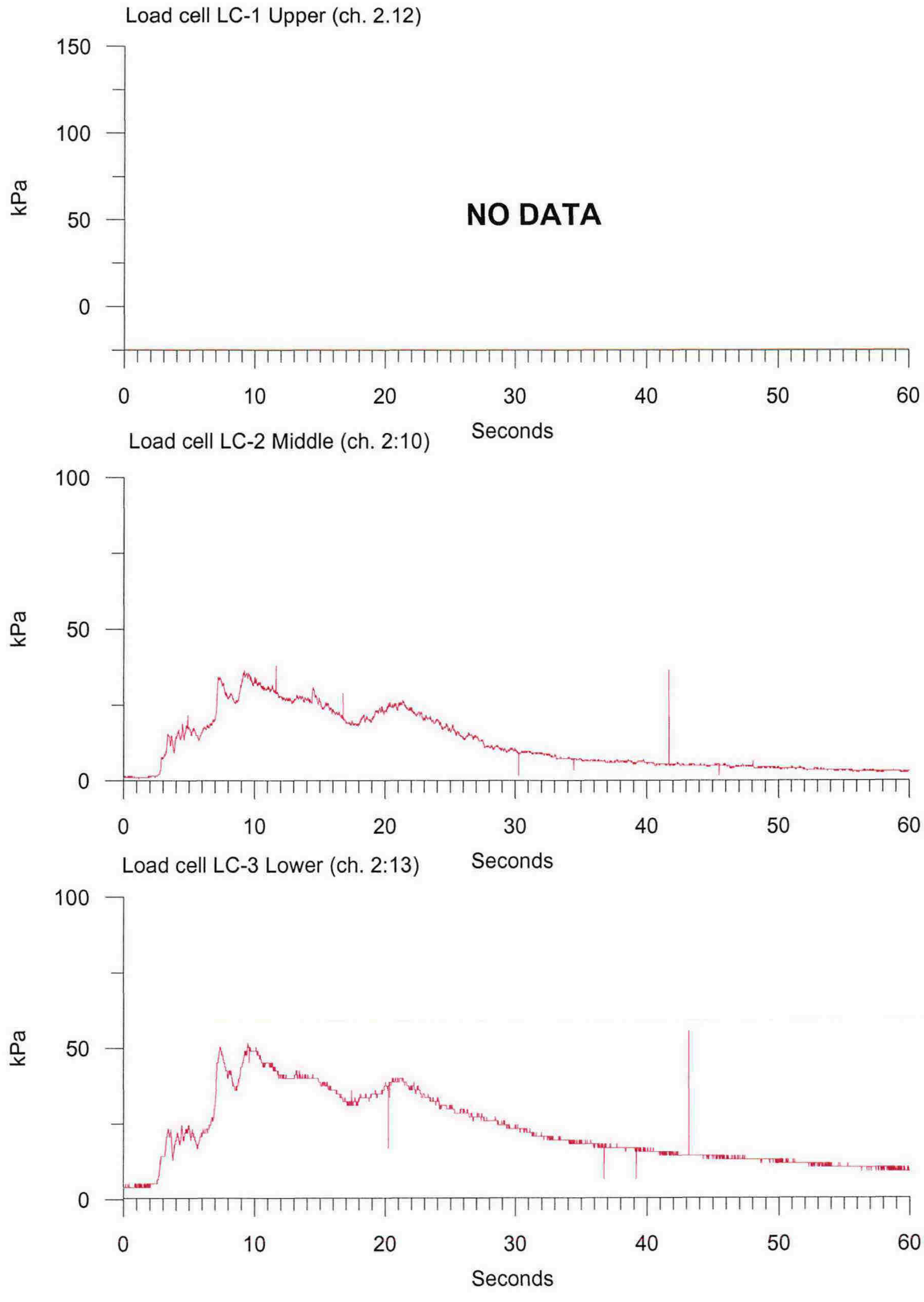
	Revised	NGI
	Approved	



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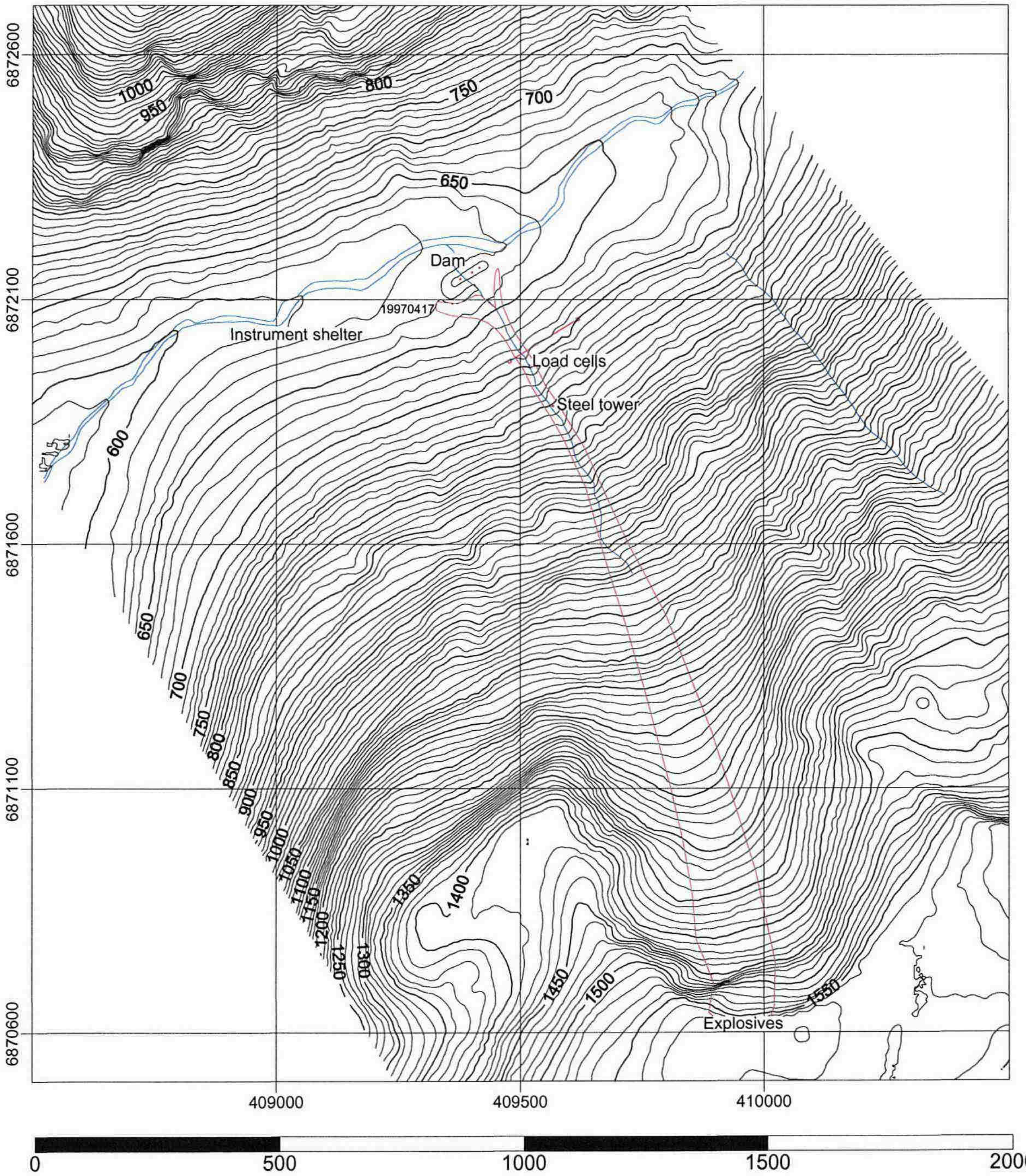

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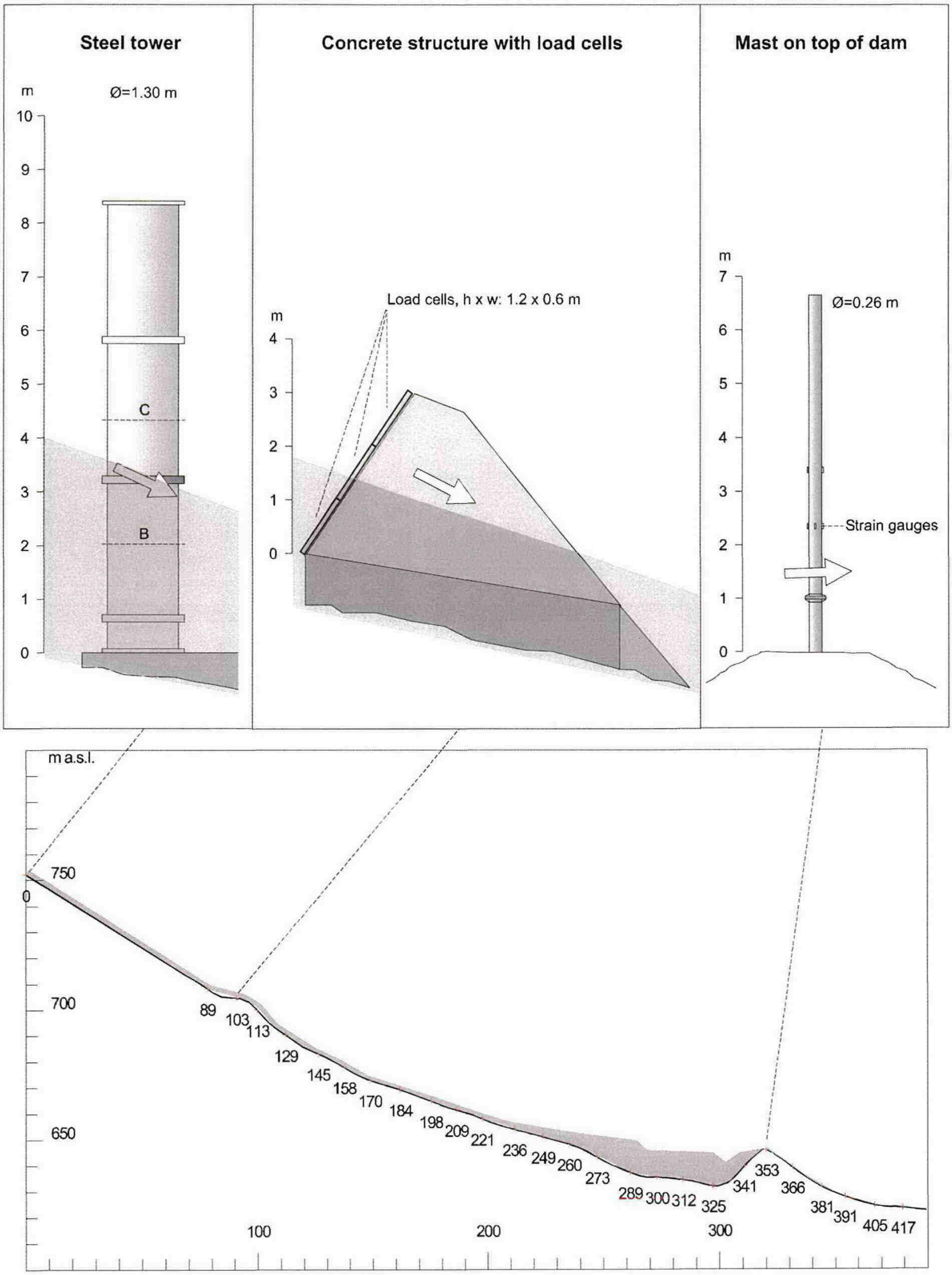
	Revised	
	Approved	NGI



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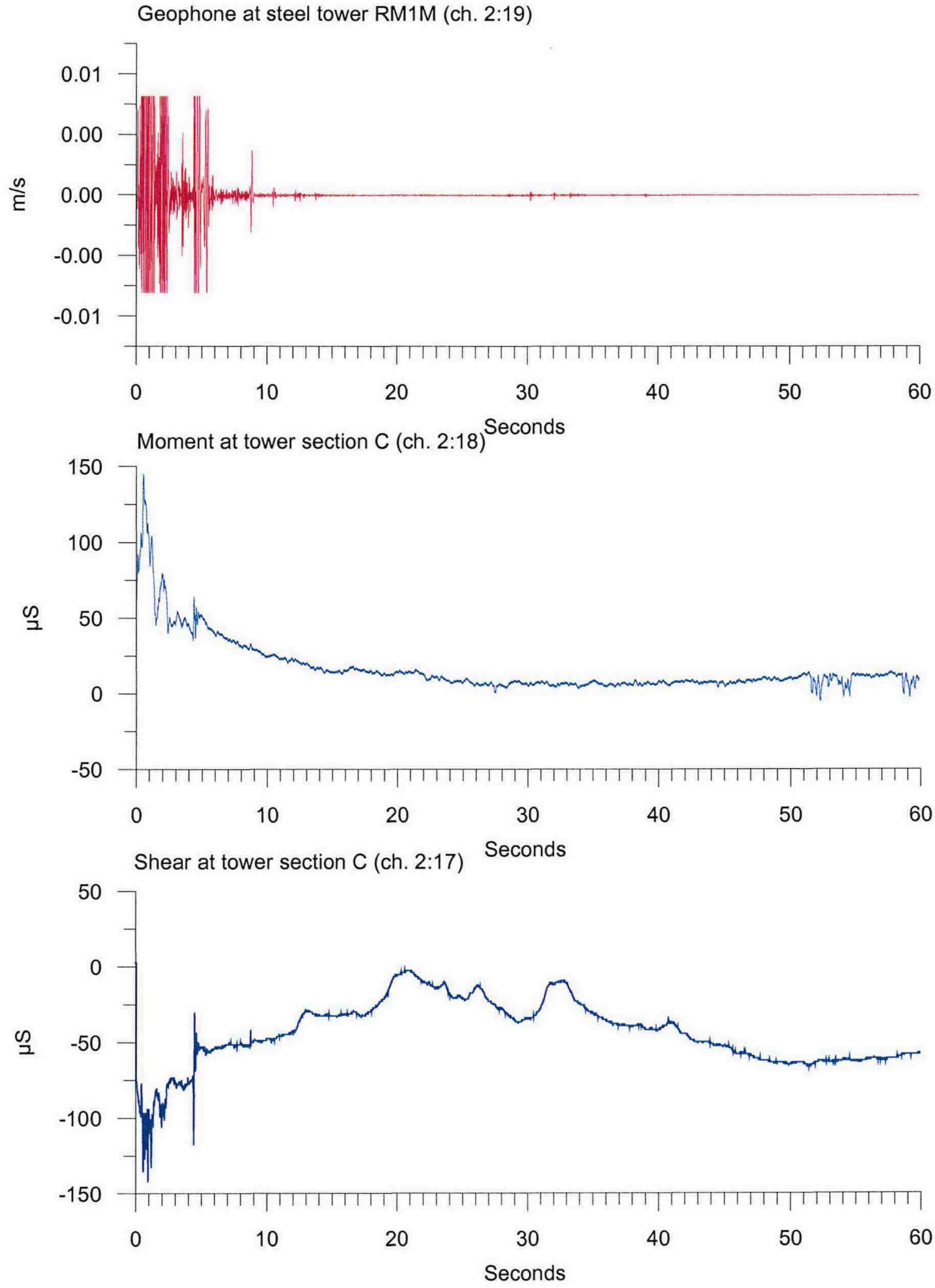
	Revised	
	Approved	NGI



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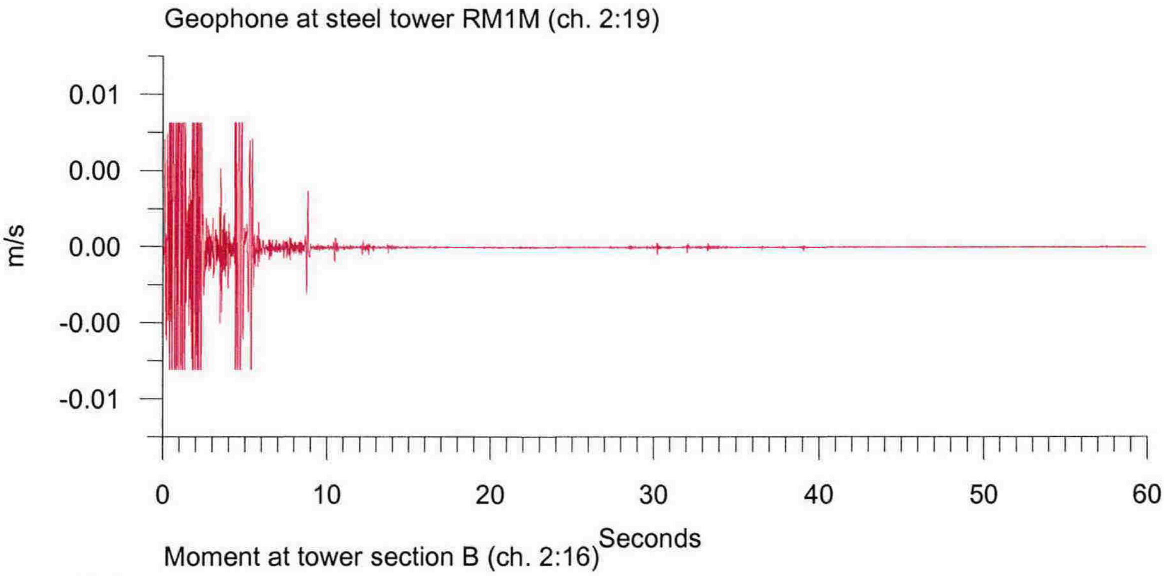
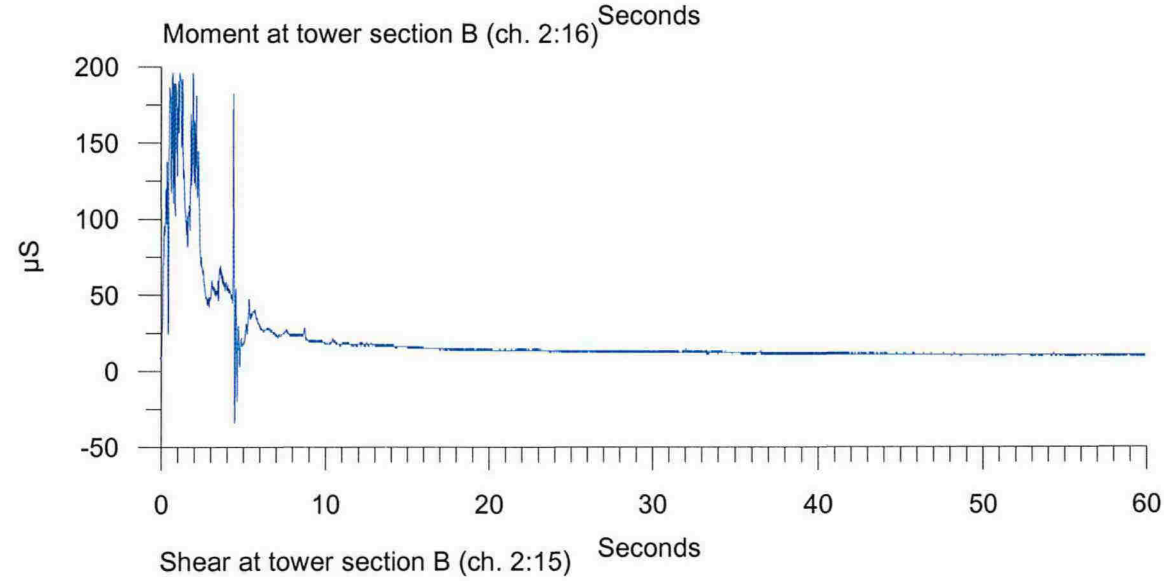
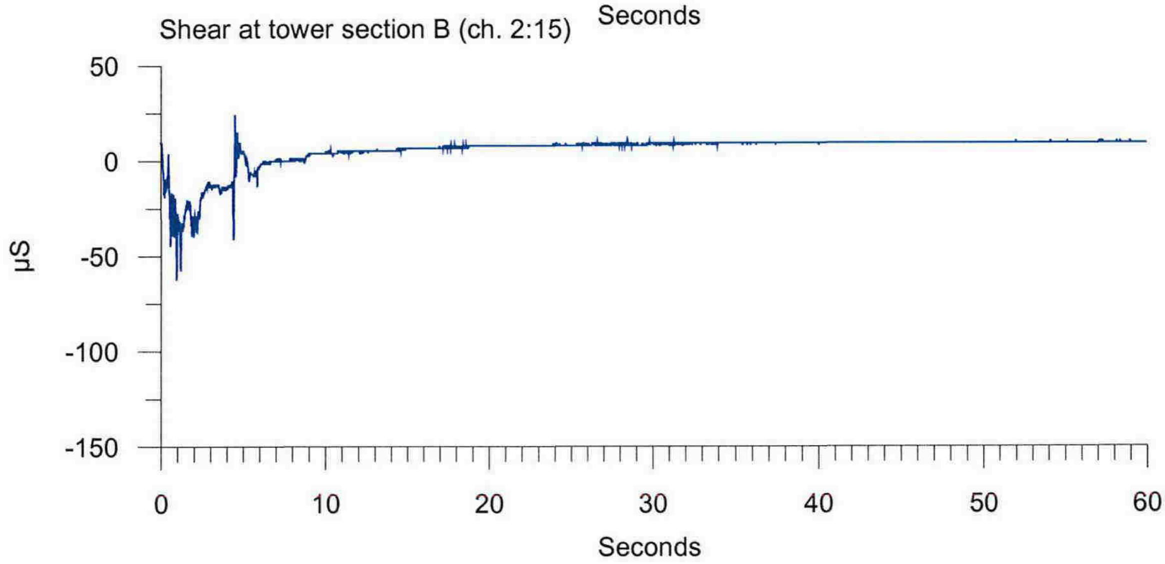
	Revised	NGI
	Approved	







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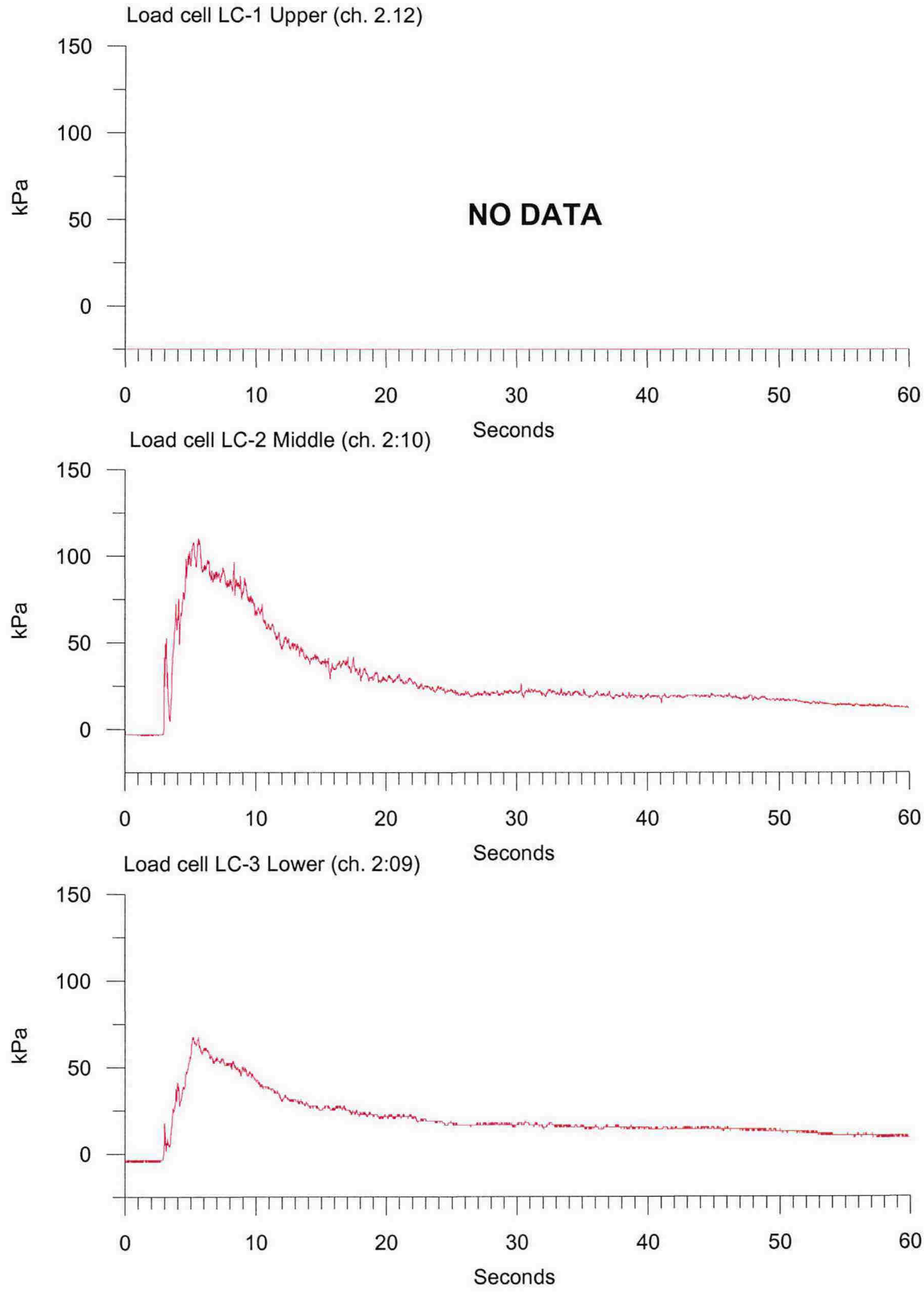
	Revised	NGI
	Approved	



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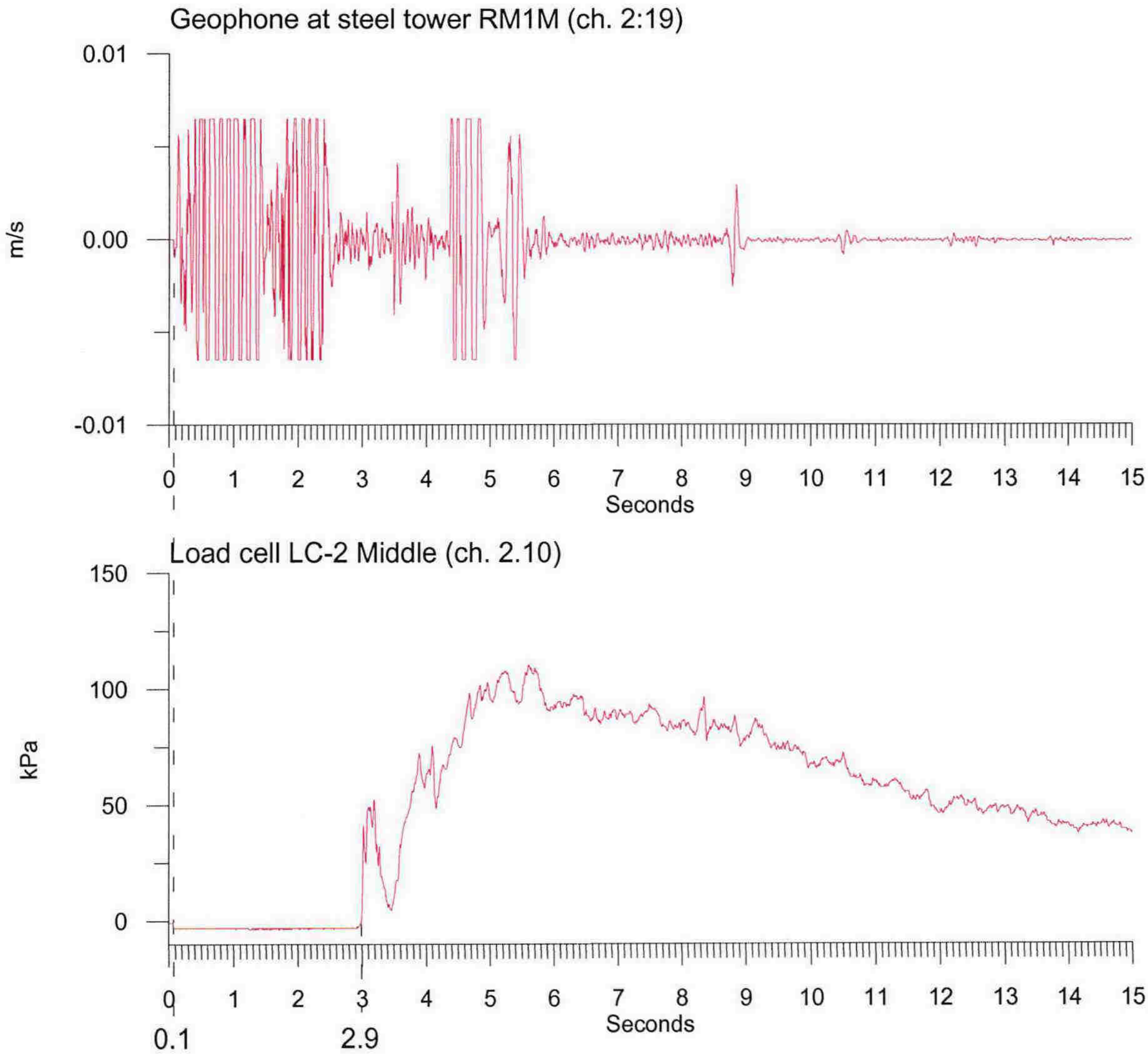

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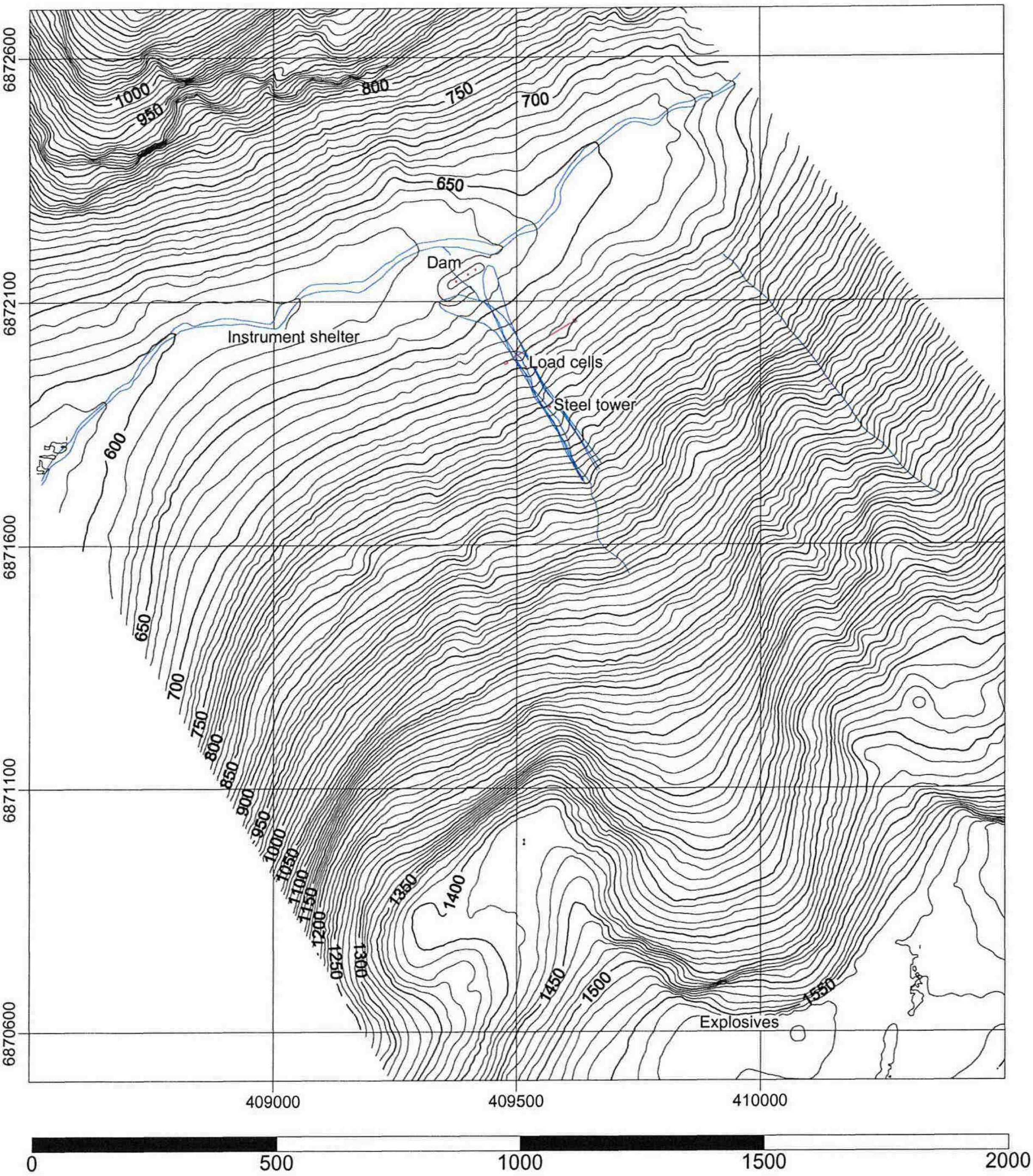
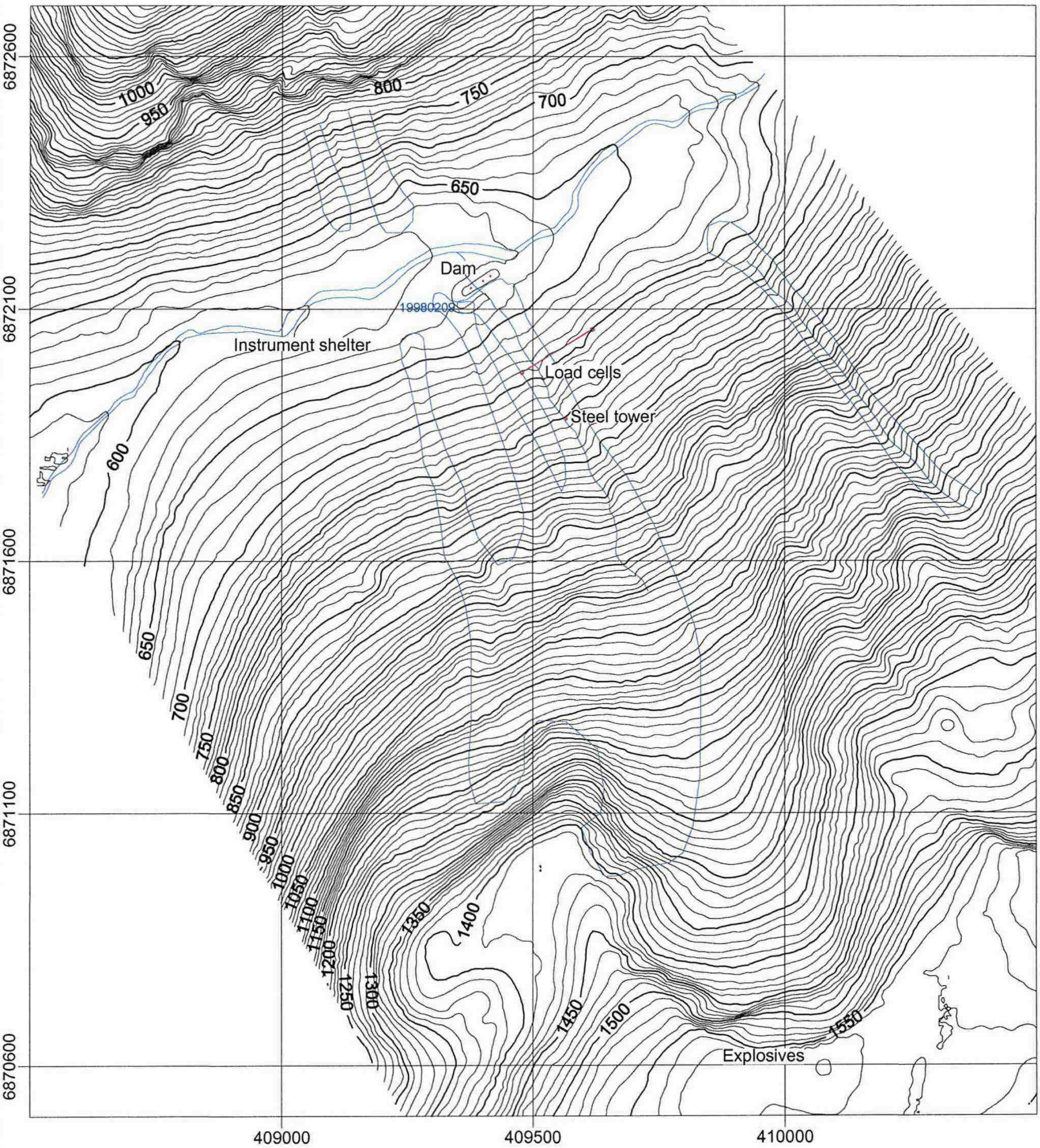
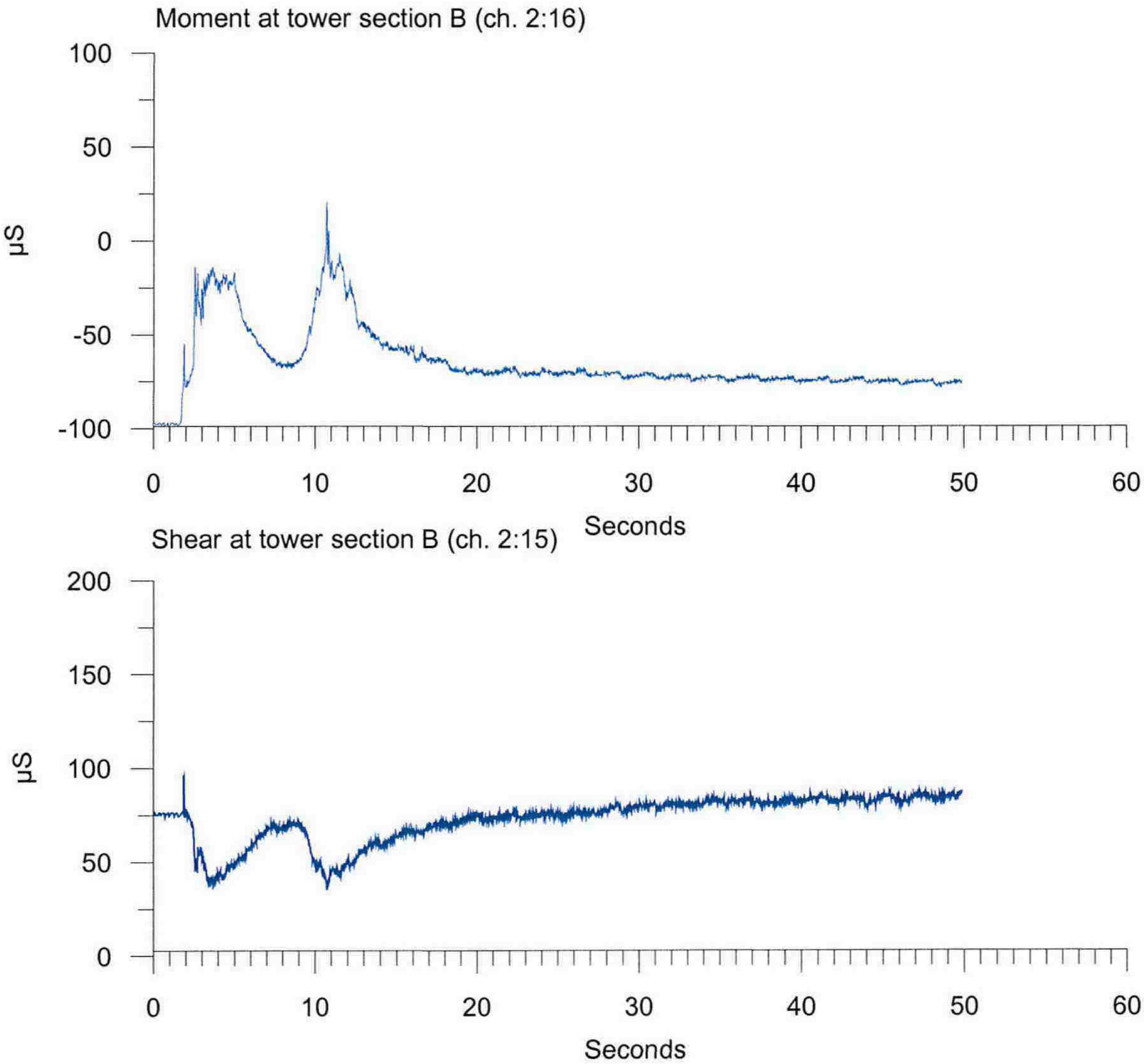
Avalanche 1997-04-17	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



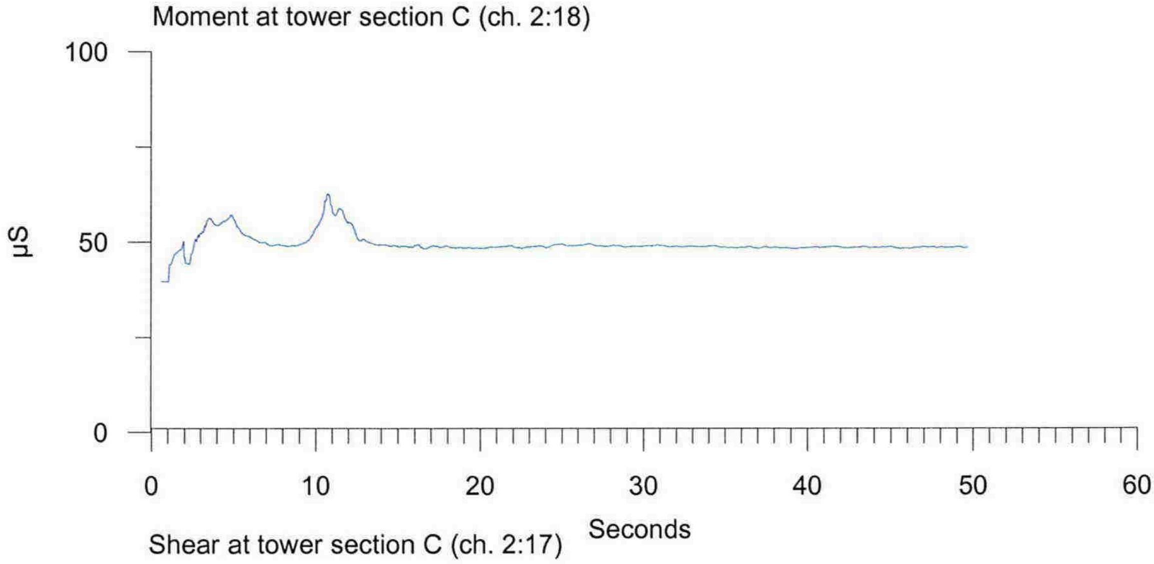
RYGGFONN	Report No. 581200-33	Figure No. 34.
Avalanches in May 1997	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI

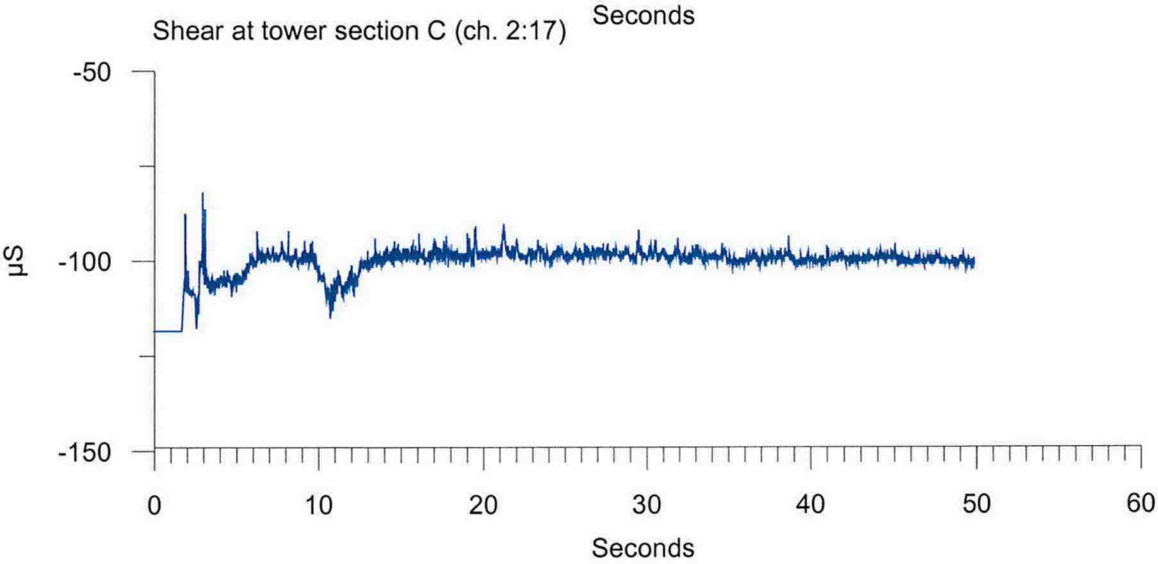


RYGGFONN	Report No. 581200-33	Figure No. 35.
Avalanche 1998-02-09	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

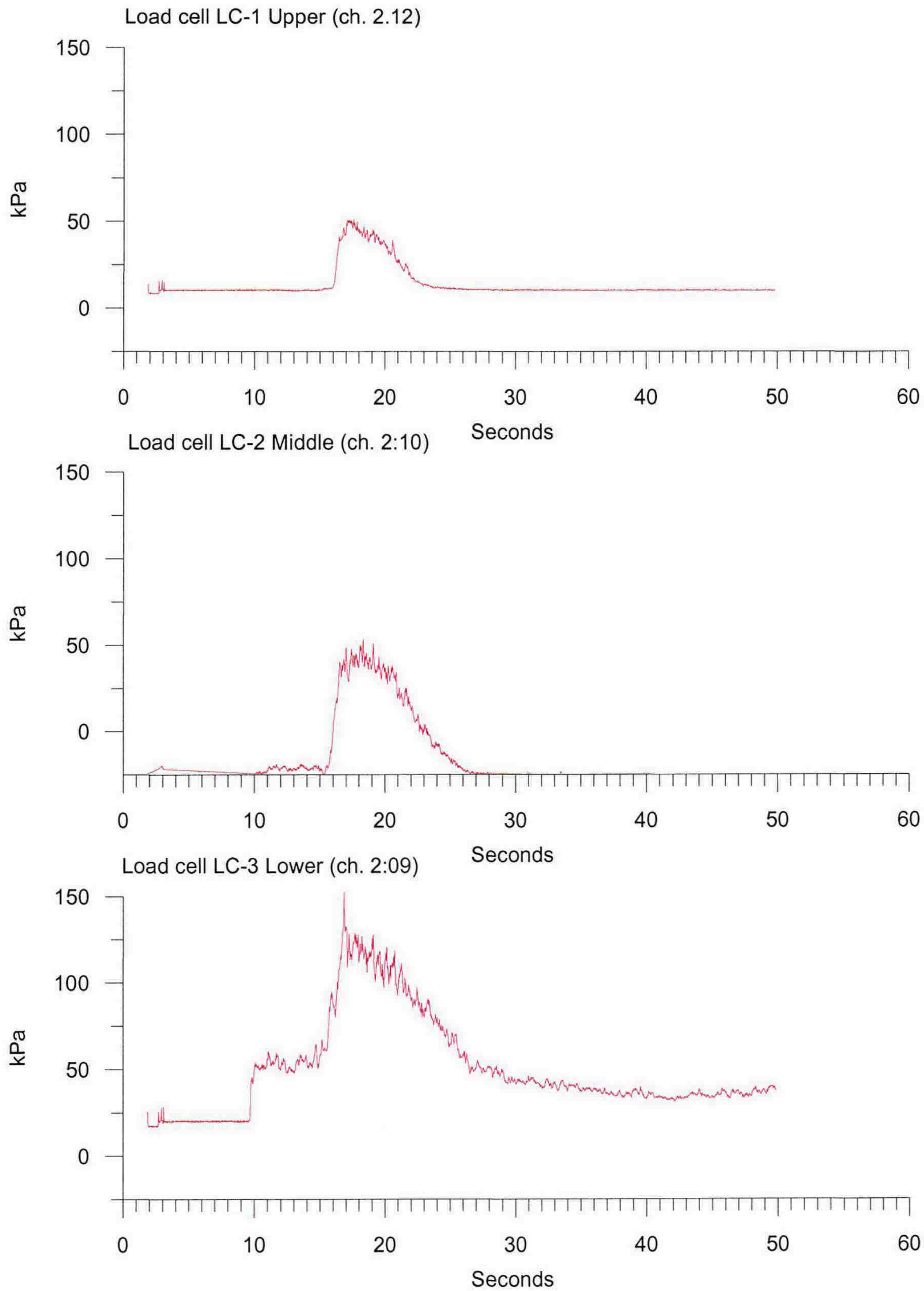


RYGGFONN	Report No. 581200-33	Figure No. 36.
Avalanche 1998-02-09	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

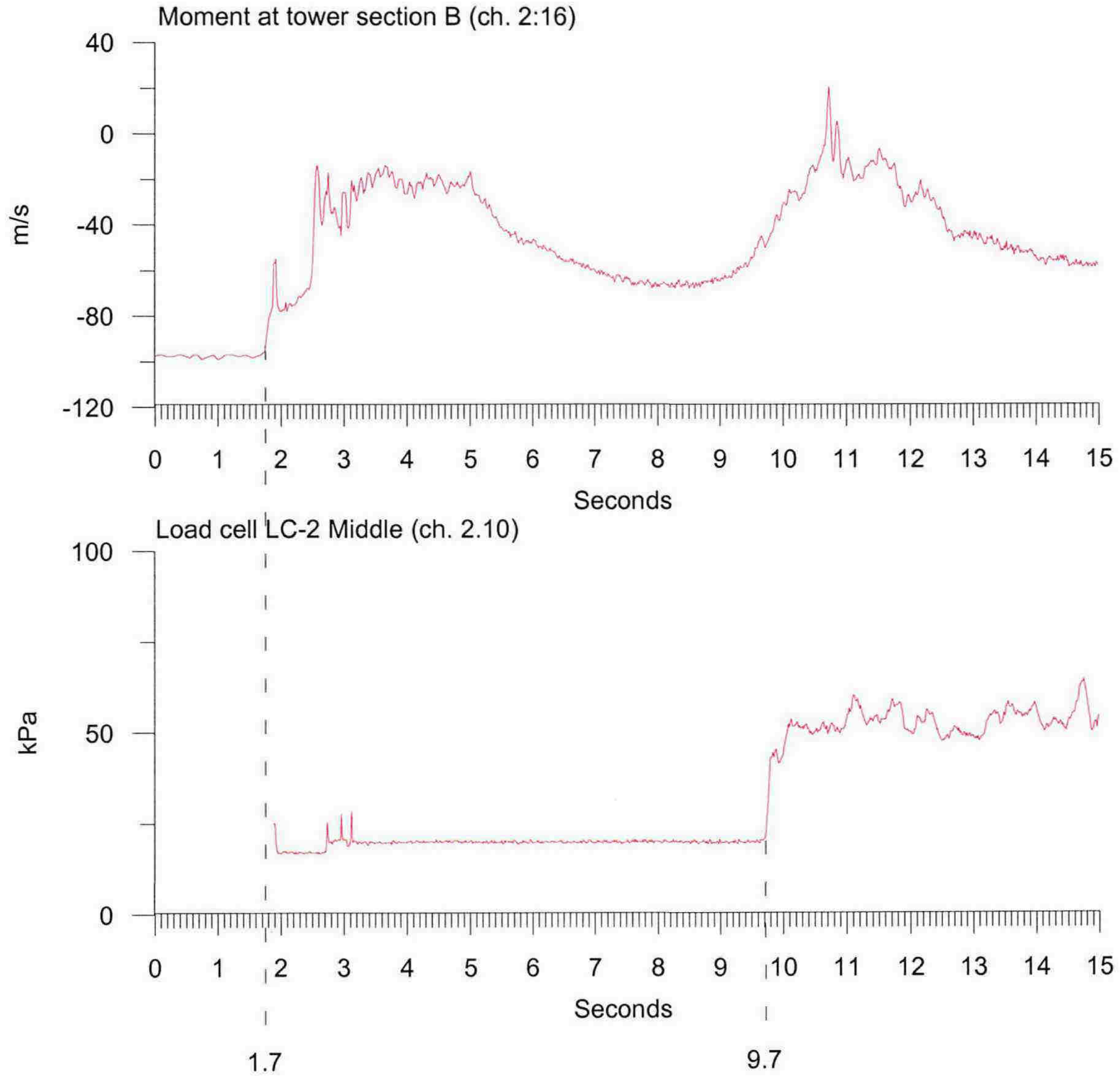




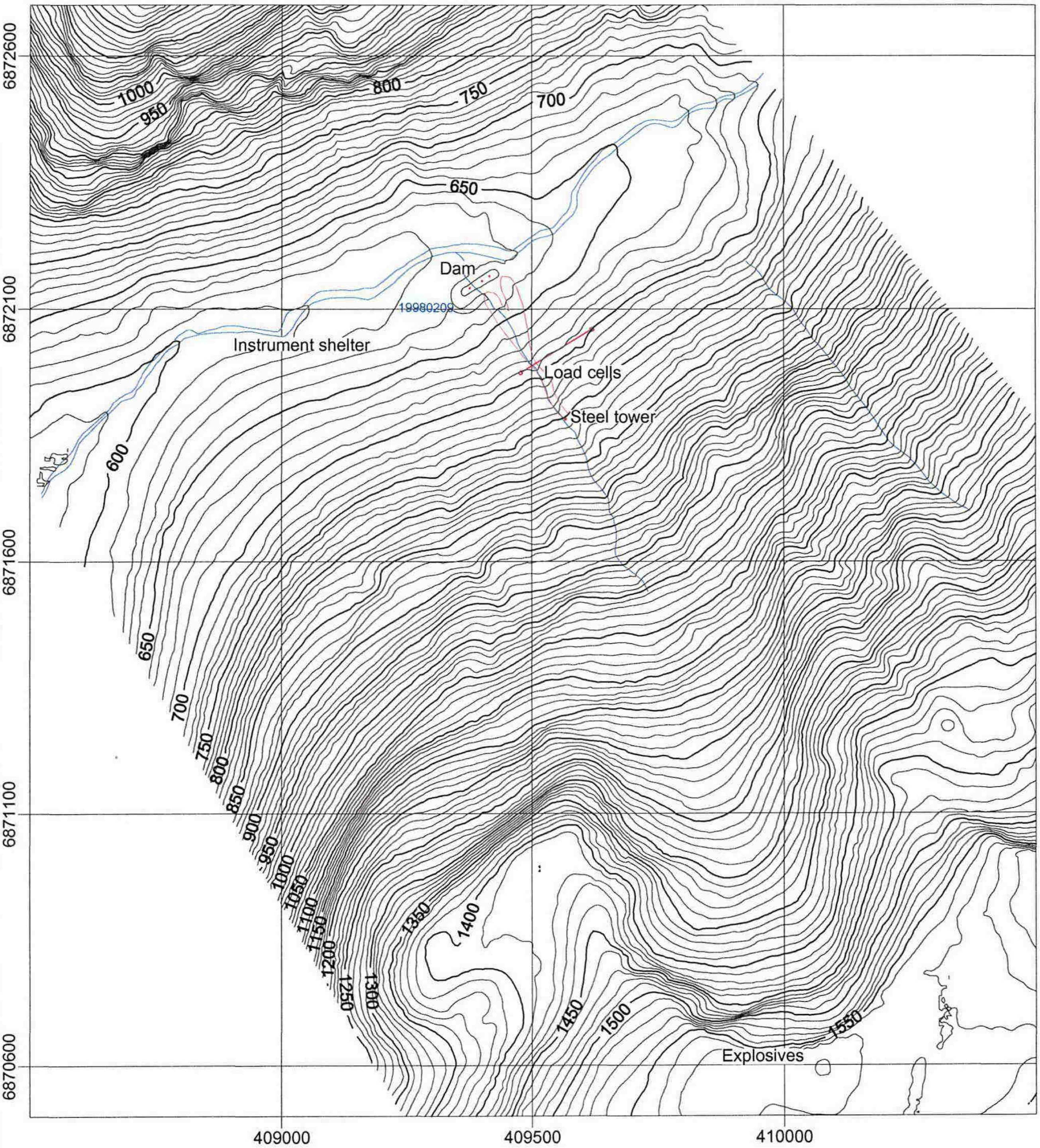
RYGGFONN	Report No. 581200-33	Figure No. 37.
Avalanche 1998-02-09	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 38.
Avalanche 1998-02-09	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 39.
Avalanche 1998-02-09	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 40.
Avalanche 1998-02-23	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

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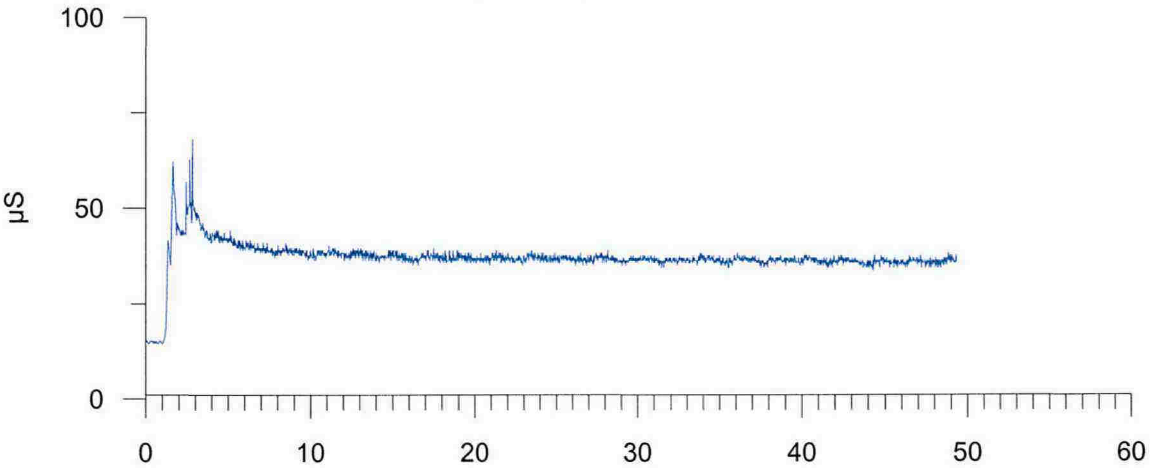
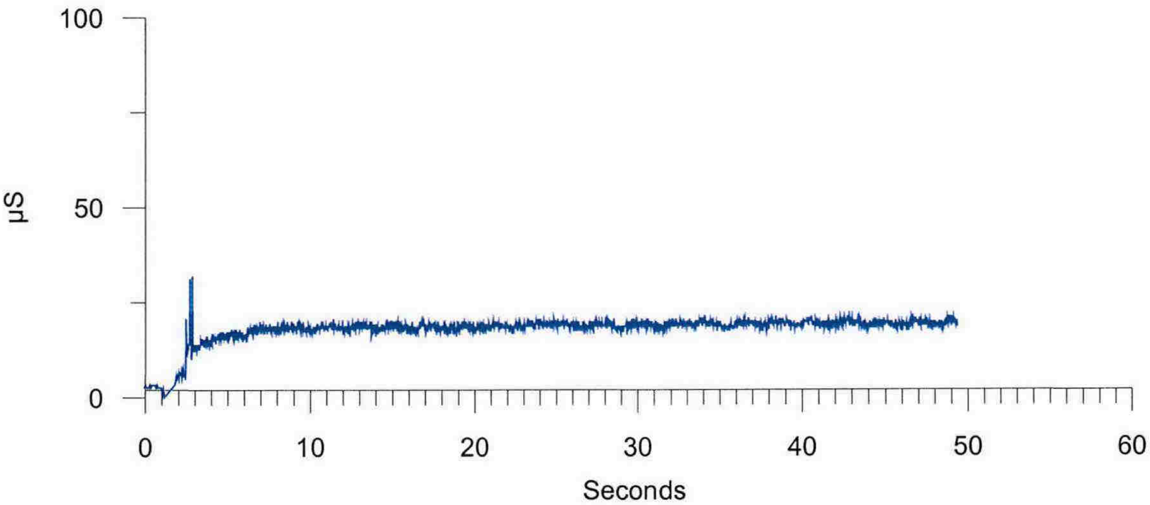
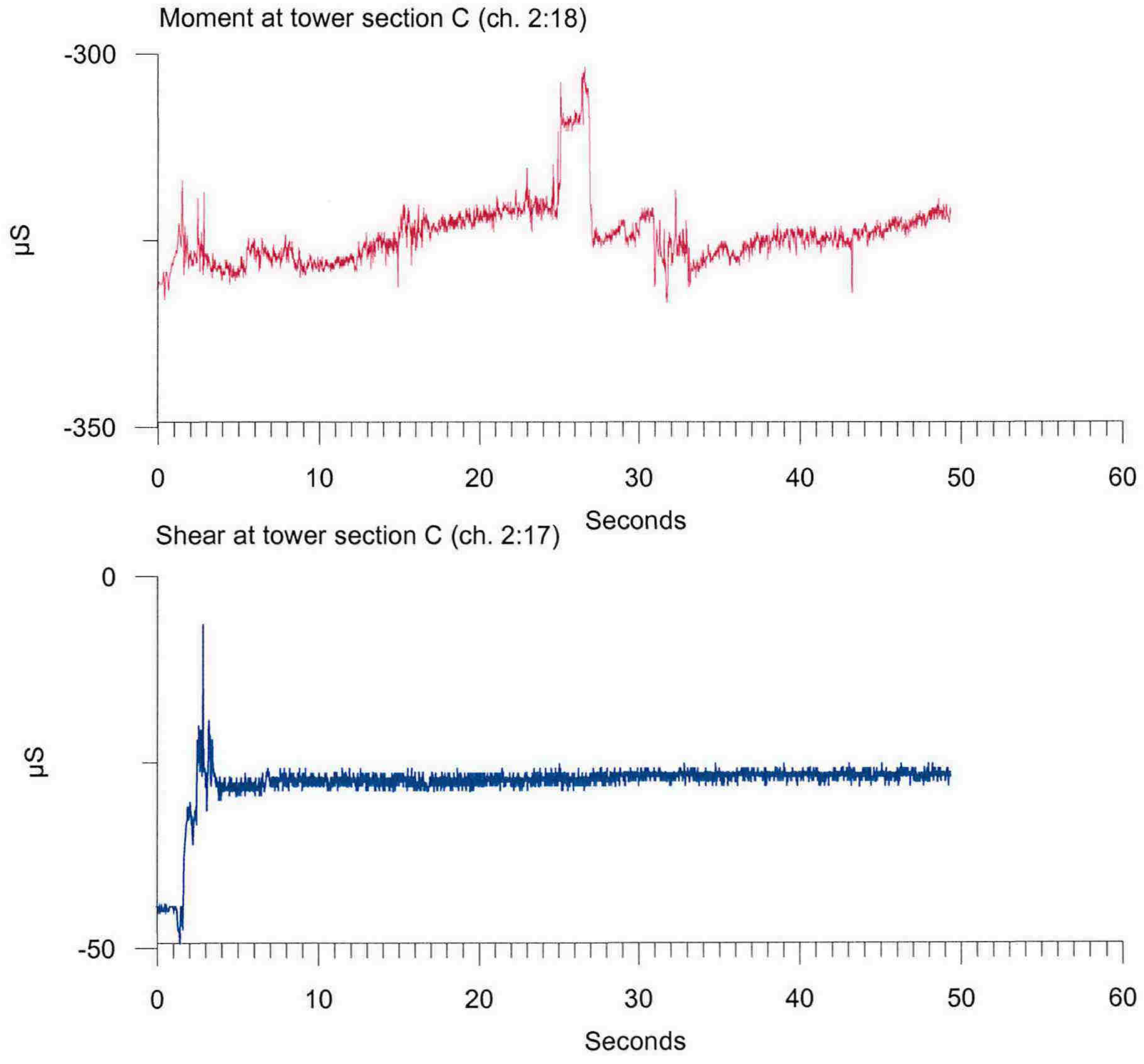
Moment at tower section B (ch. 2:16)



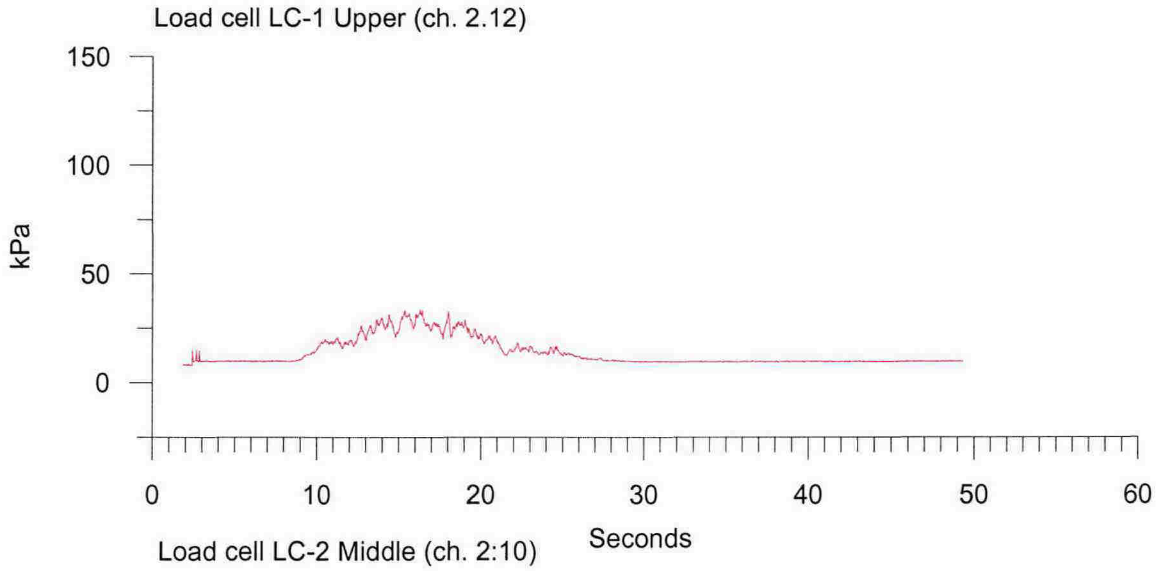
Shear at tower section B (ch. 2:15)

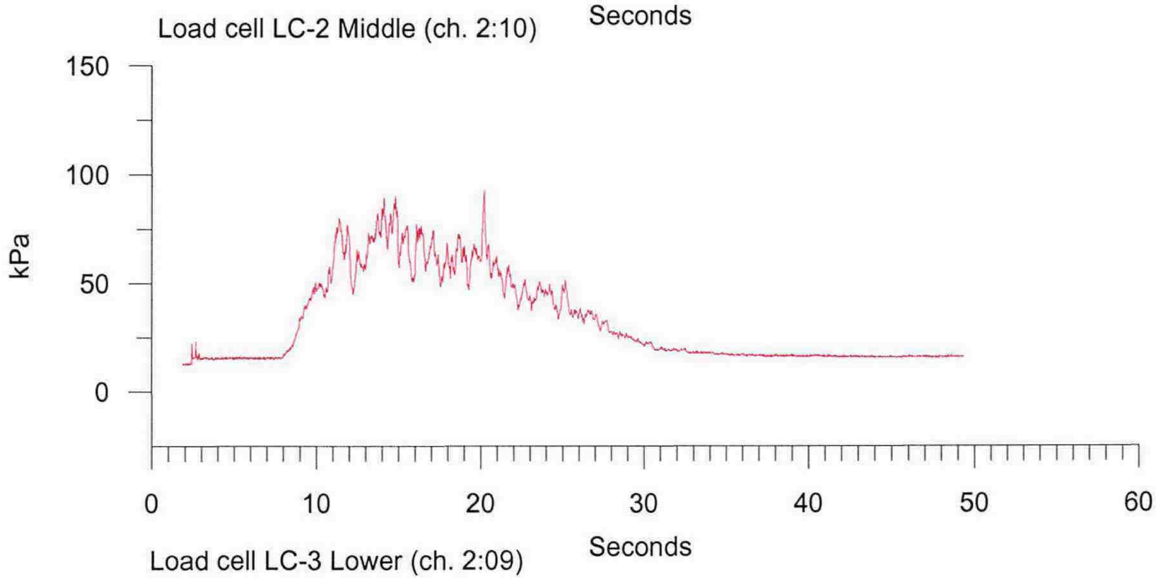


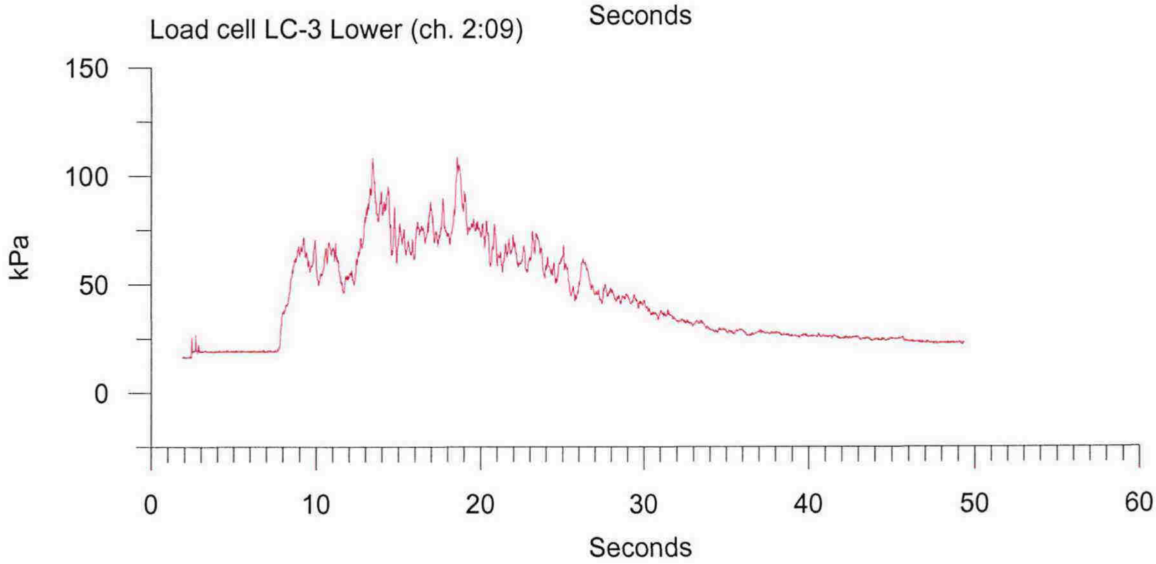
RYGGFONN	Report No. 581200-33	Figure No. 41.
Avalanche 1998-02-23	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 42.
Avalanche 1998-02-23	Drawn by KKr	Date 2001-11-01
	Revised Approved	NGI







RYGGFONN	Report No. 581200-33	Figure No. 43.
Avalanche 1998-02-23	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

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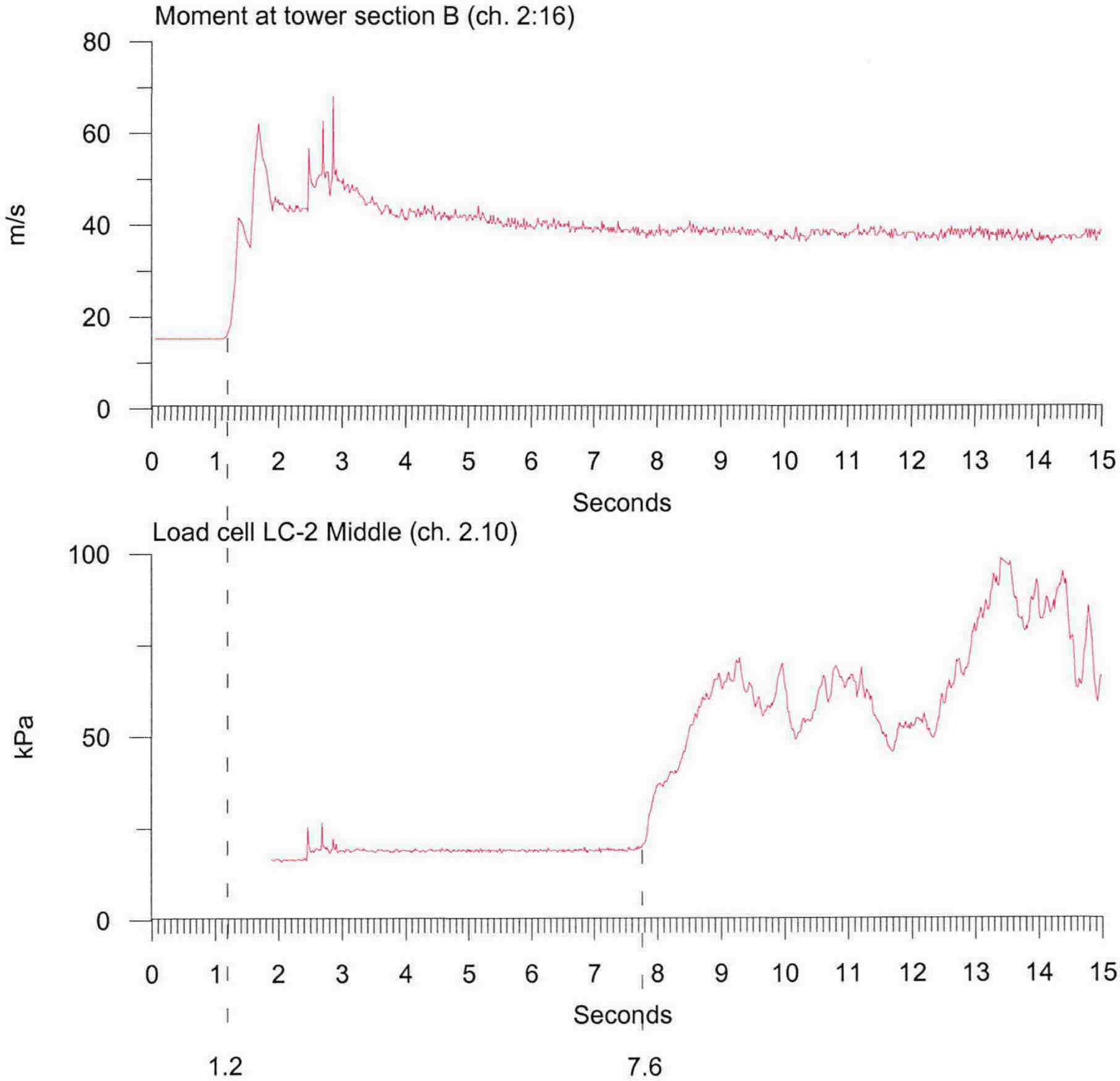
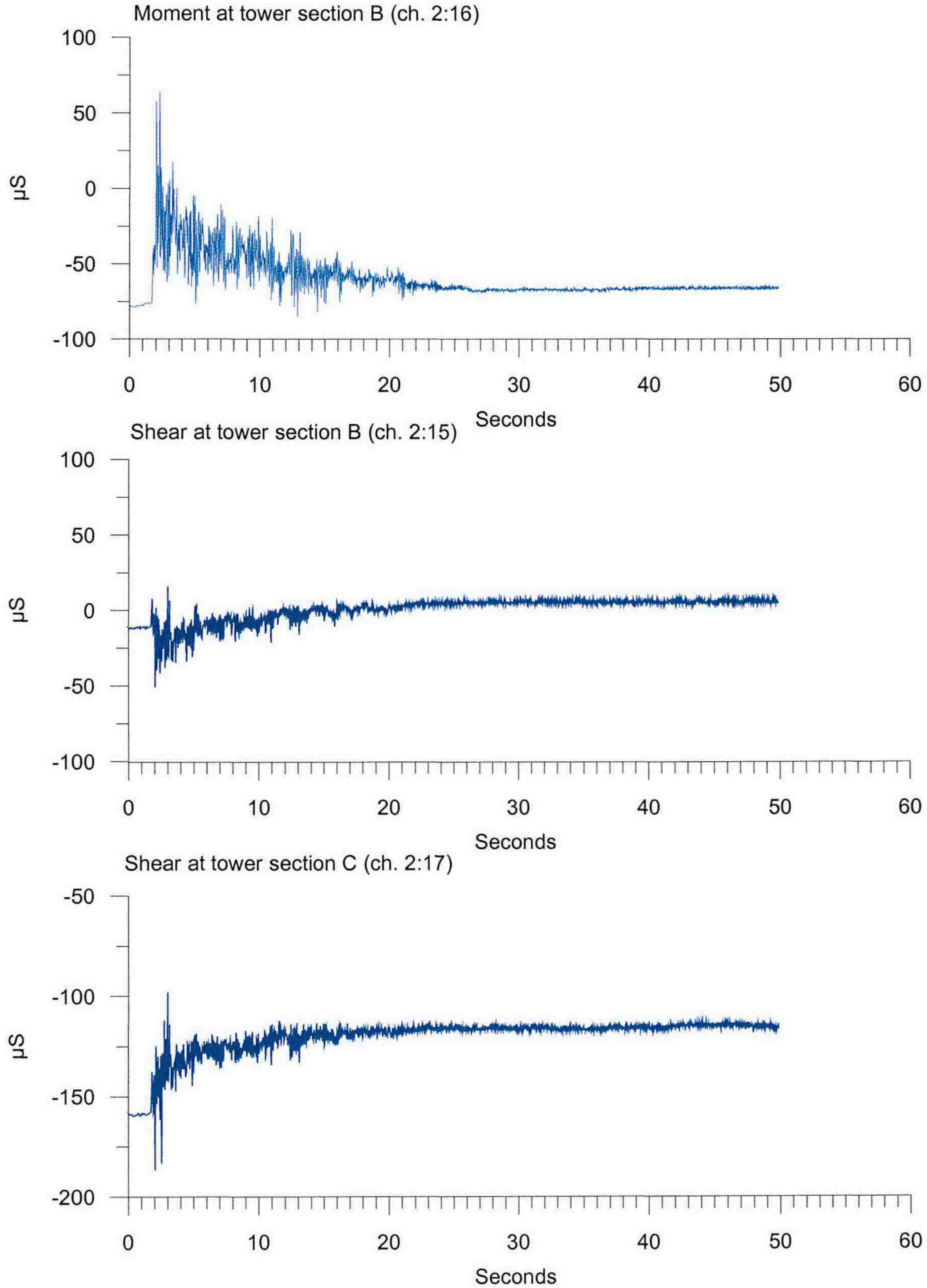
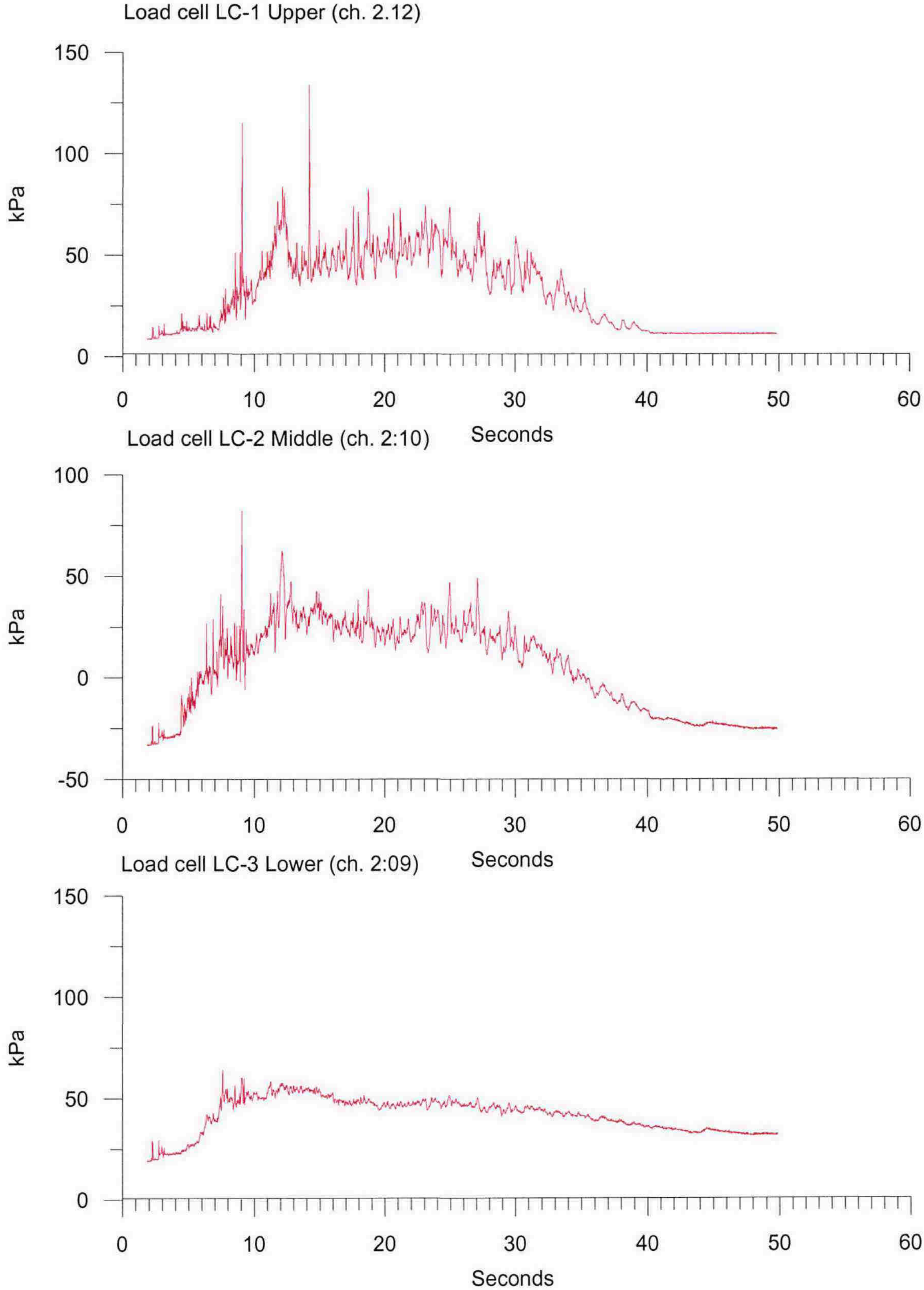


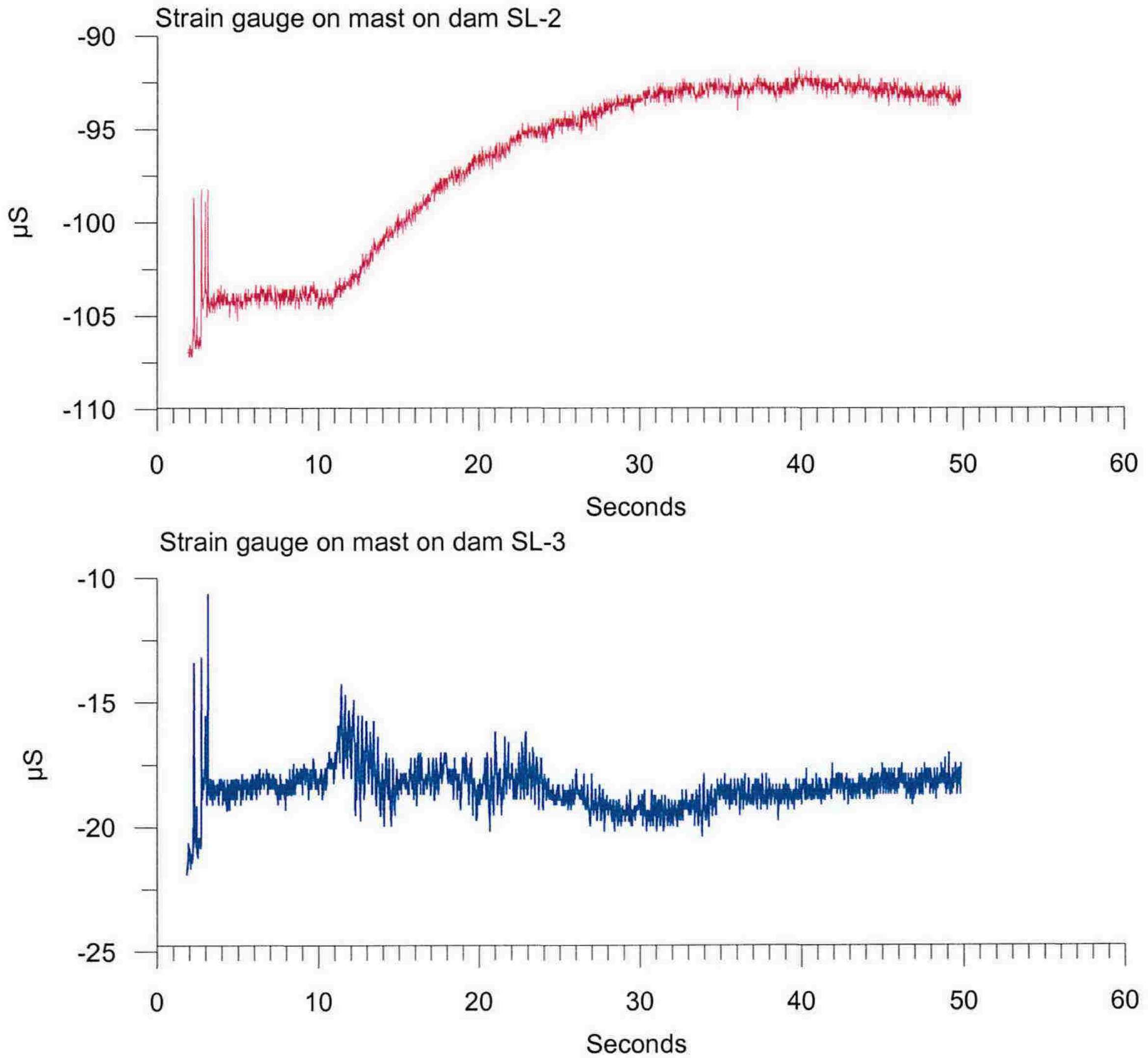
RYGGFONN	Report No. 581200-33	Figure No. 44.
Avalanche 1998-02-23	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



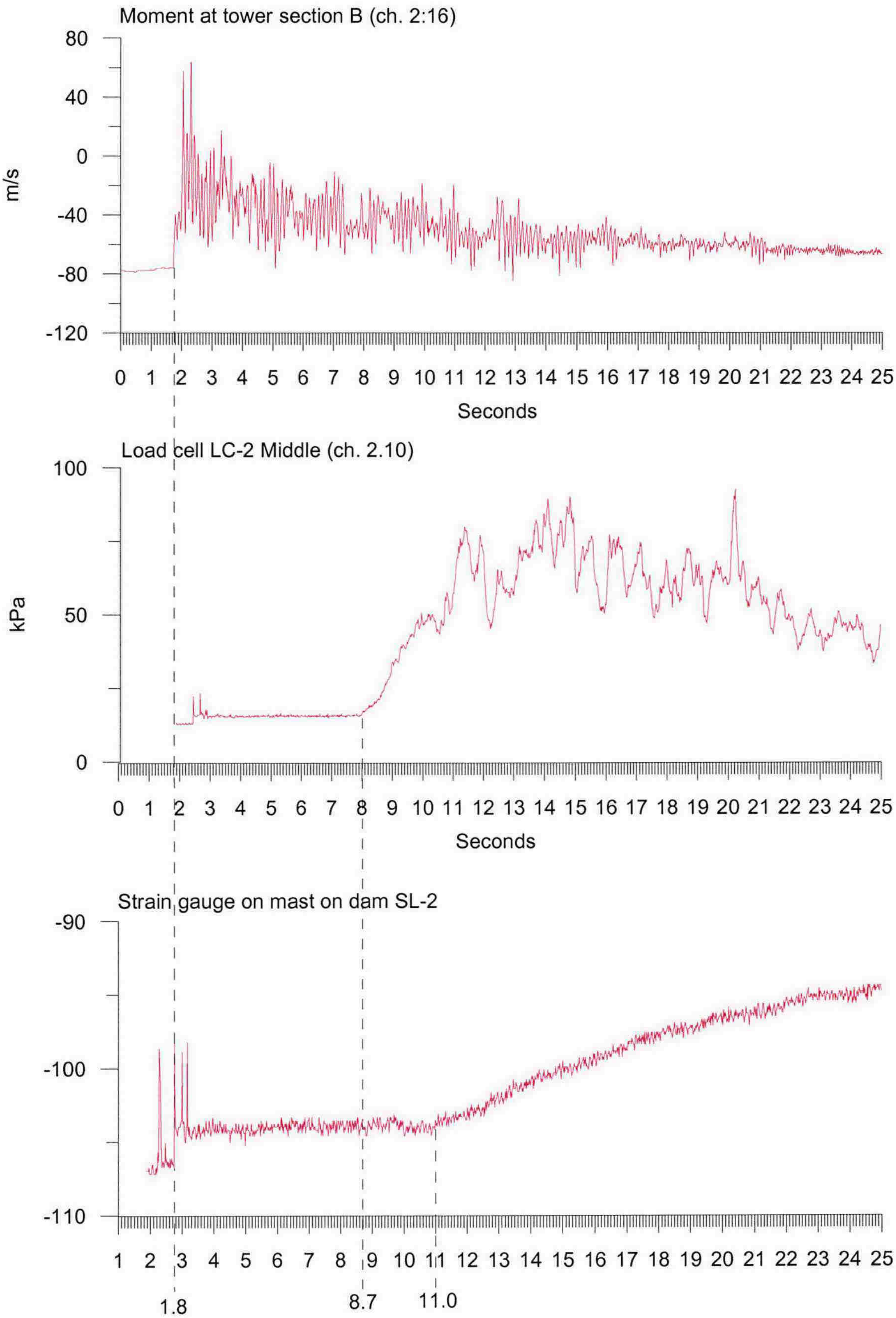
RYGGFONN	Report No. 581200-33	Figure No. 45.
Avalanche 1998-03-26	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



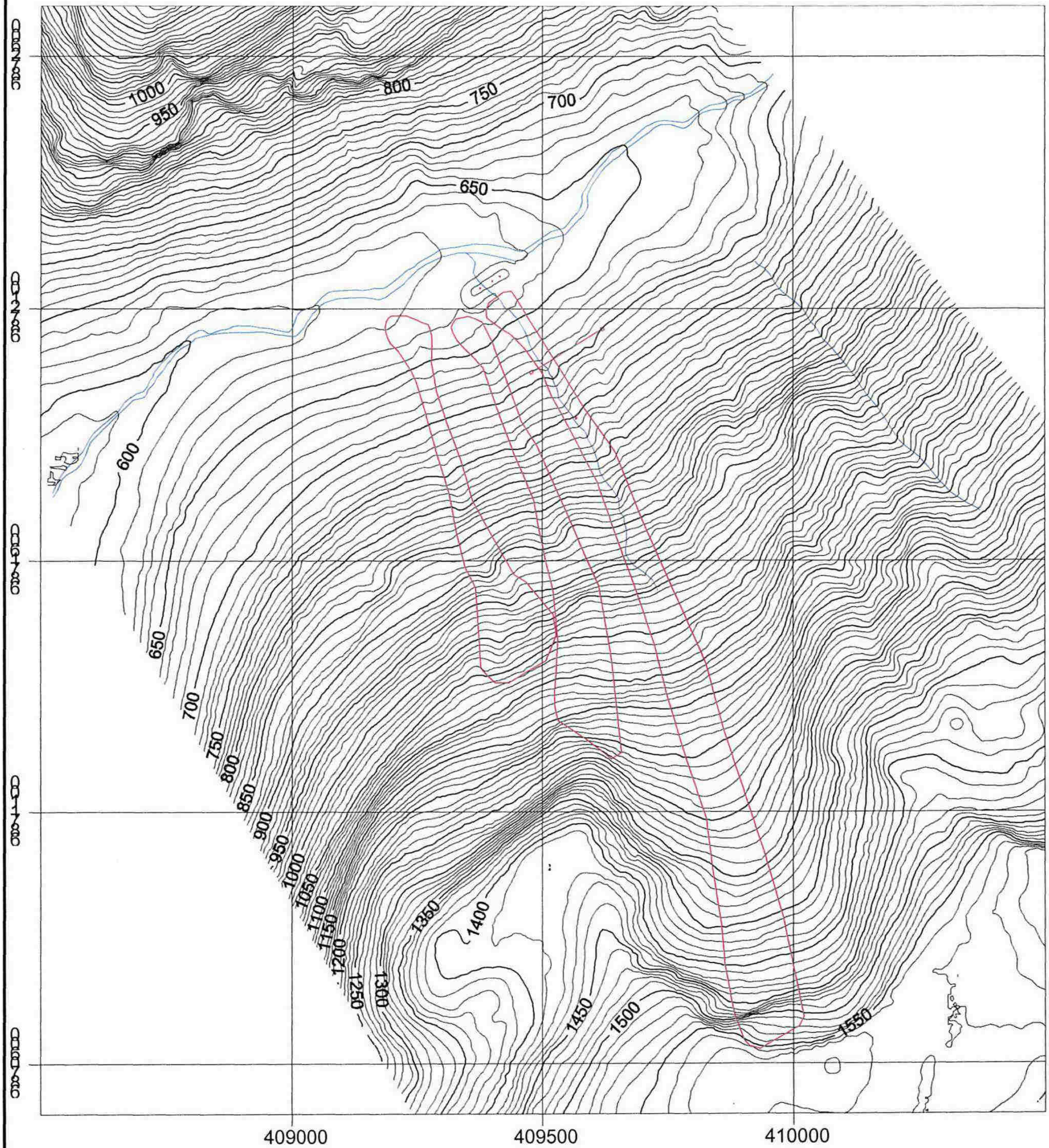
RYGGFONN	Report No. 581200-33	Figure No. 46.
Avalanche 1998-03-26	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



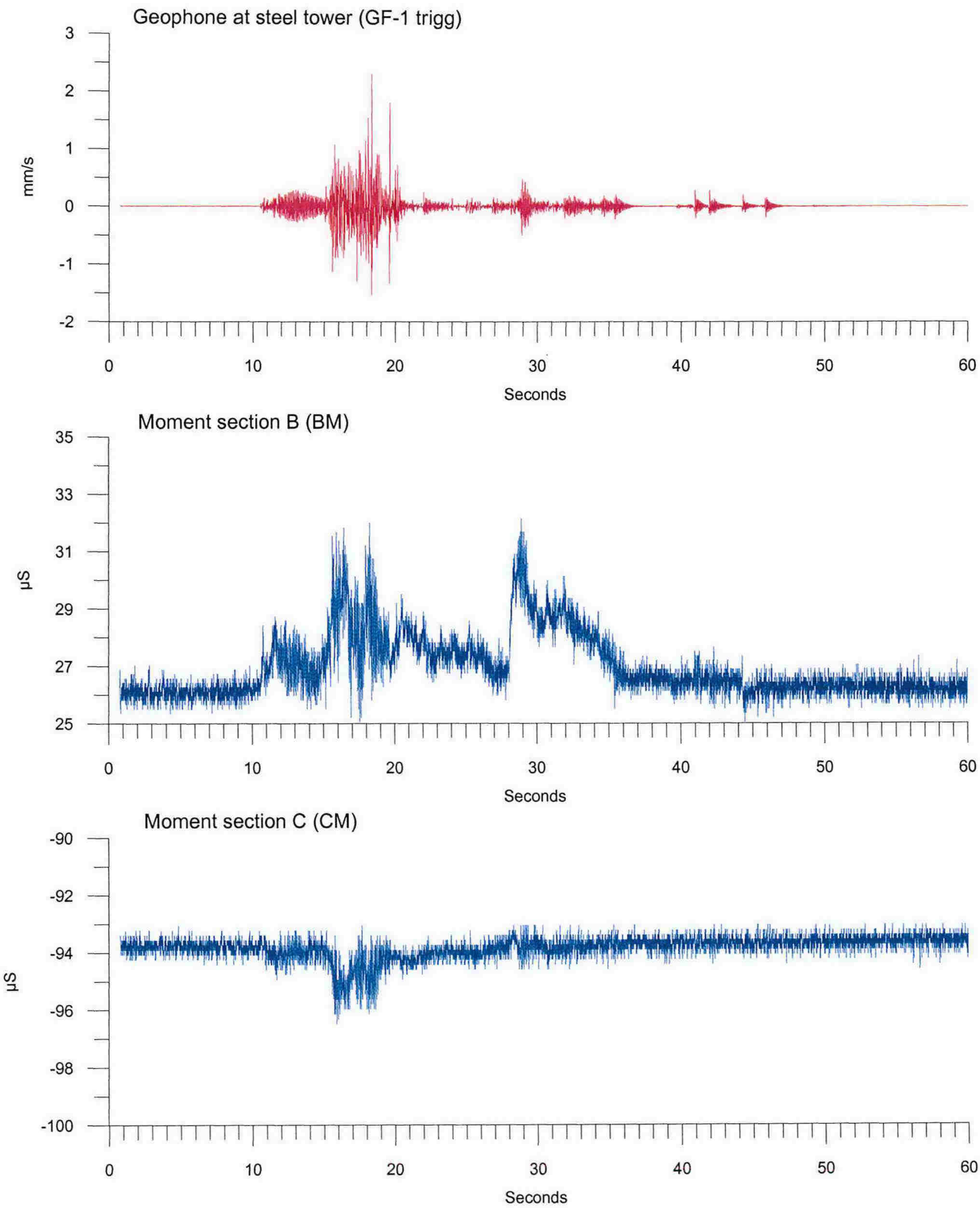
RYGGFONN	Report No. 581200-33	Figure No. 47.
Avalanche 1998-03-26	Drawn by KKr KKr KKr	Date 2001-11-01
	Revised	
	Approved	NGI



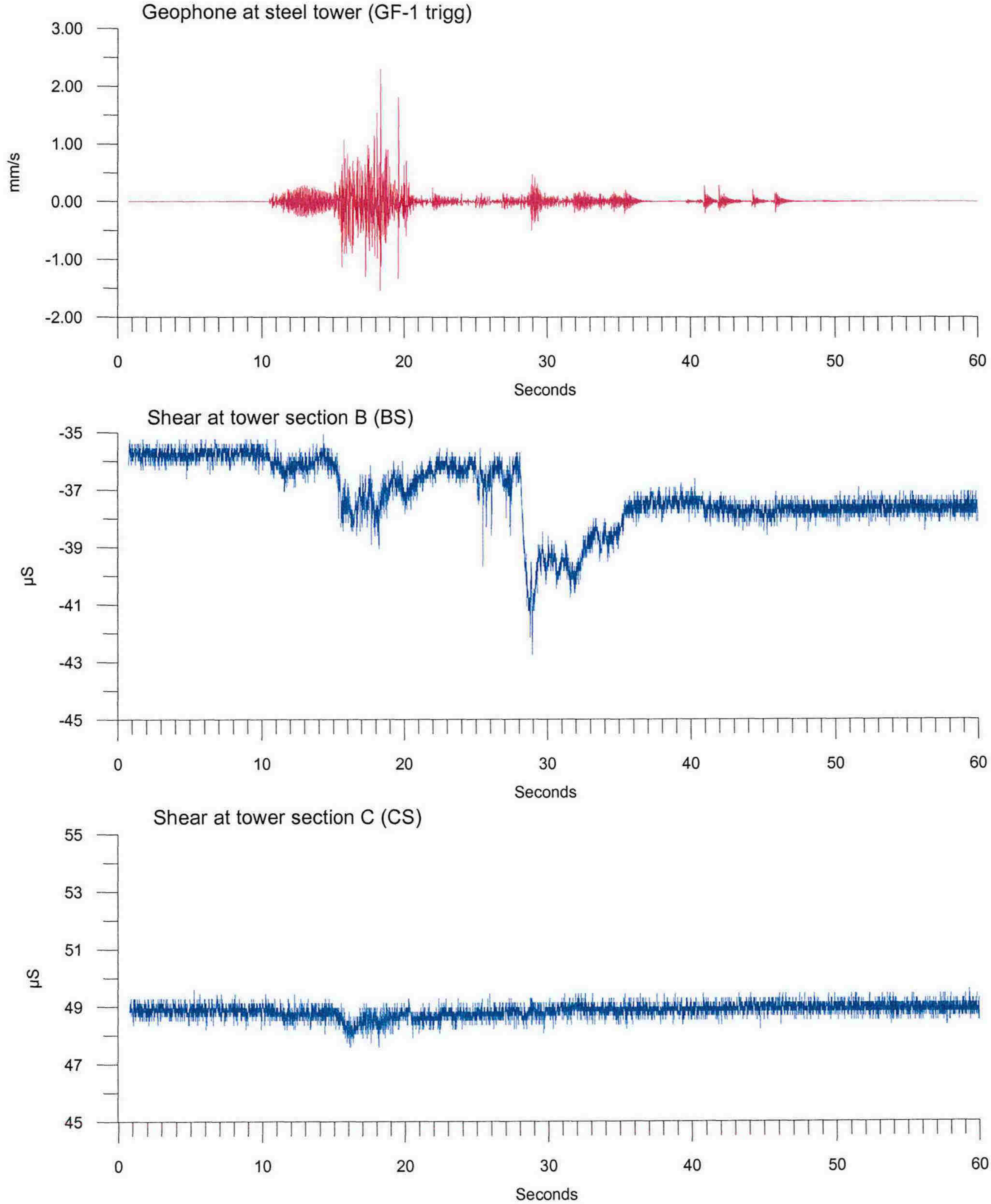
RYGGFONN	Report No. 581200-33	Figure No. 48.
Avalanche 1998-03-26	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



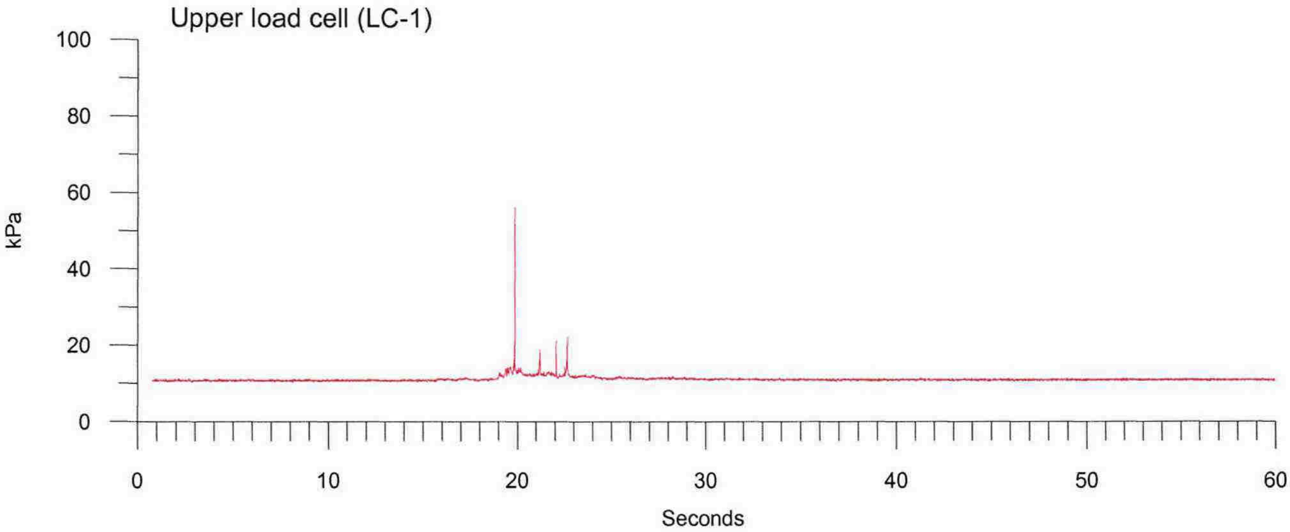
RYGGFONN	Report No. 581200-33	Figure No. 49.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

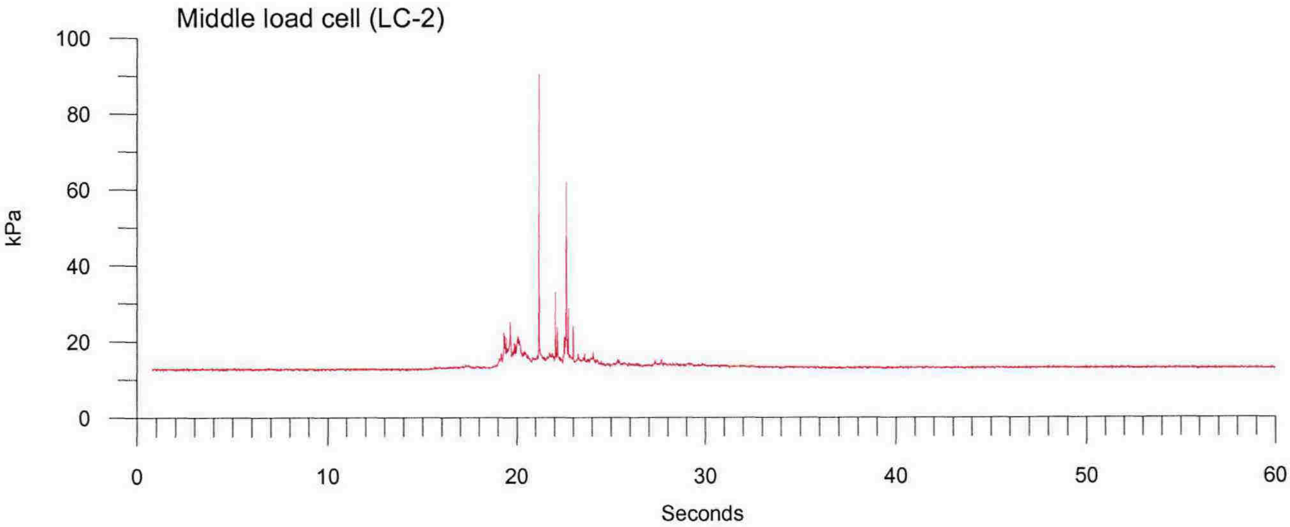


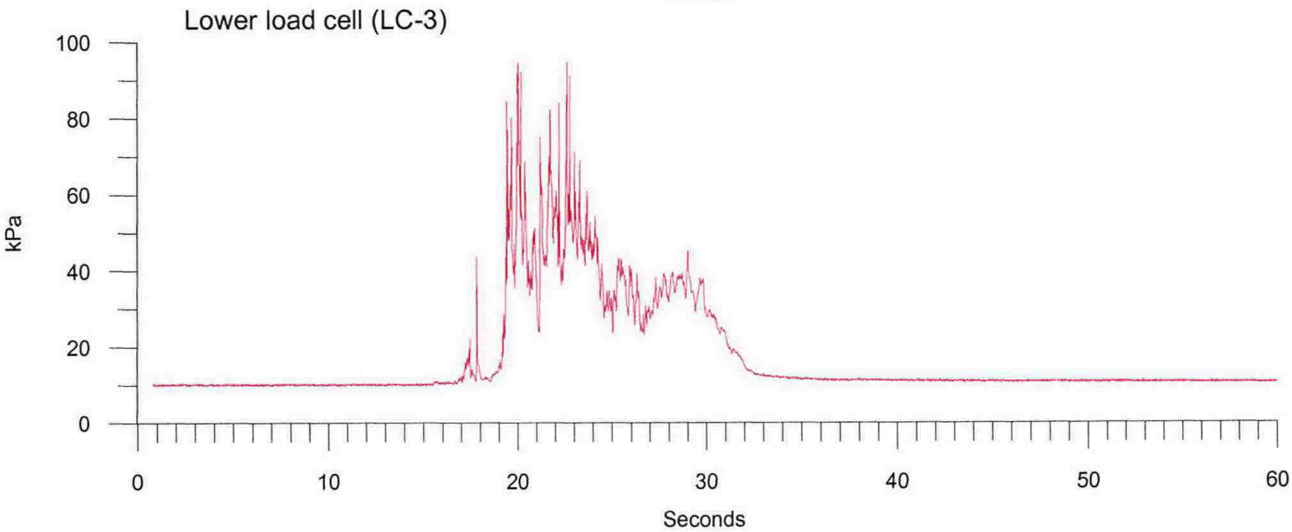
RYGGFONN	Report No. 581200-33	Figure No. 50.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



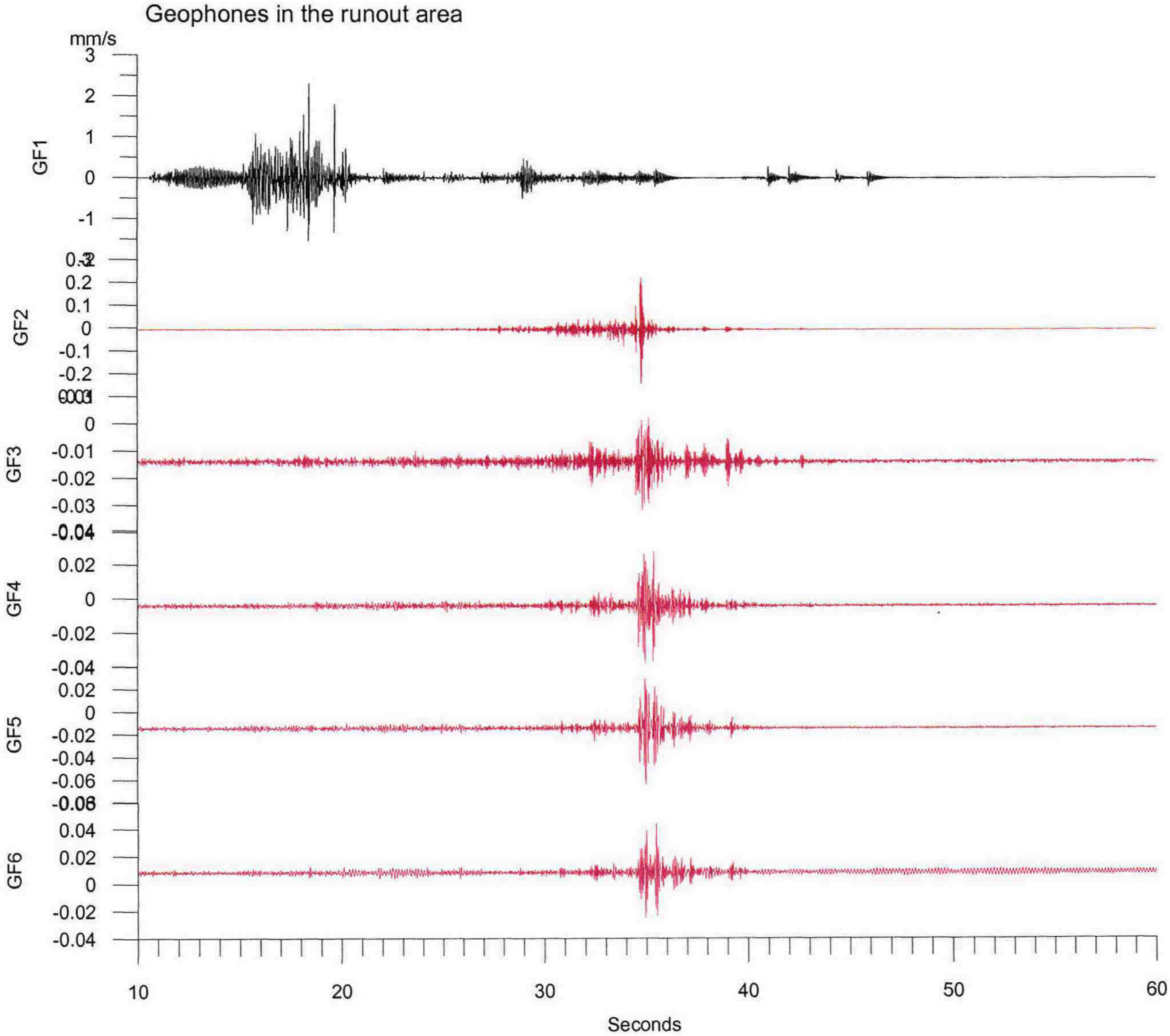
RYGGFONN	Report No. 581200-33	Figure No. 51.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



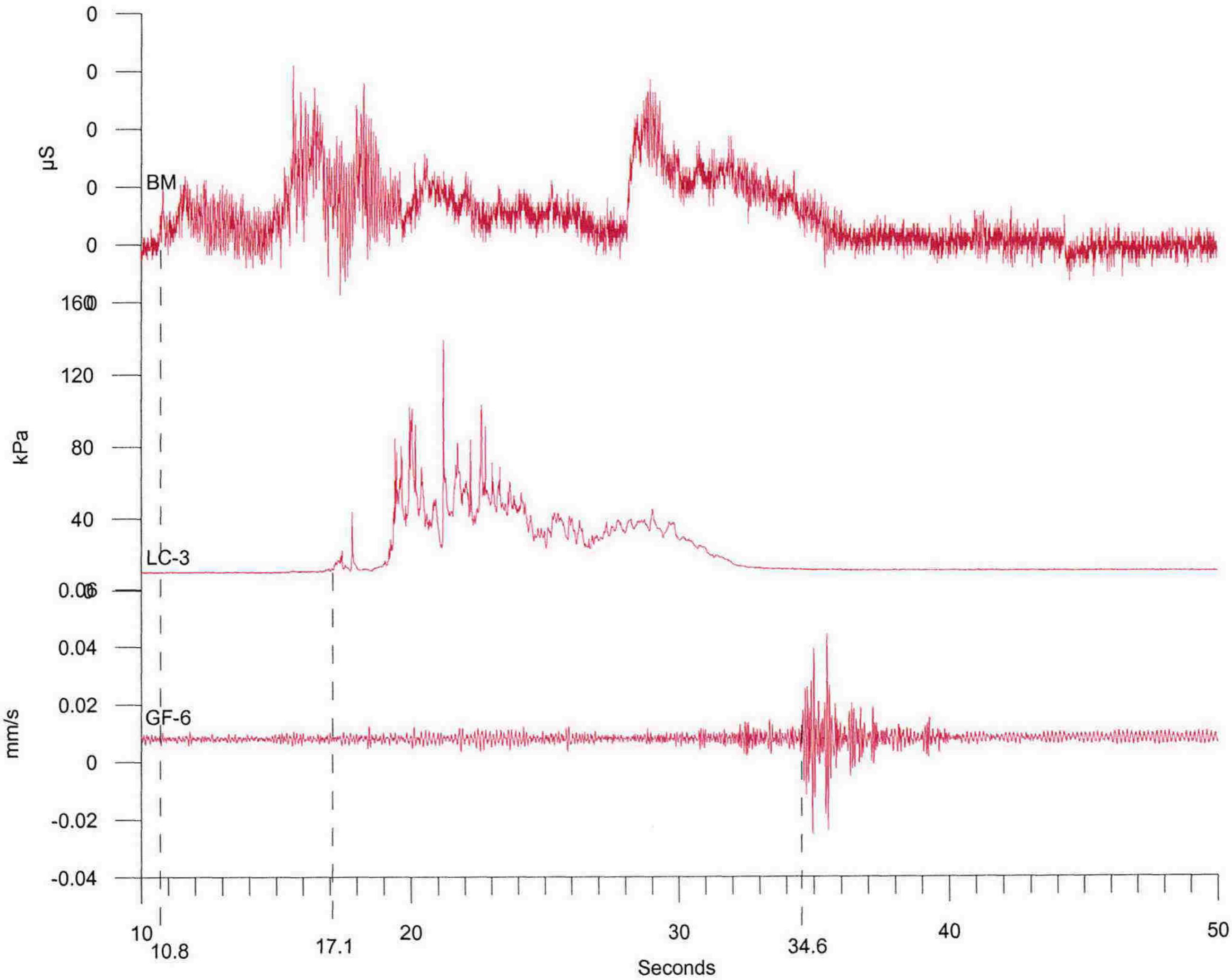




RYGGFONN	Report No. 581200-33	Figure No. 52.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 53.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 54.
Avalanche 1999-01-22	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI

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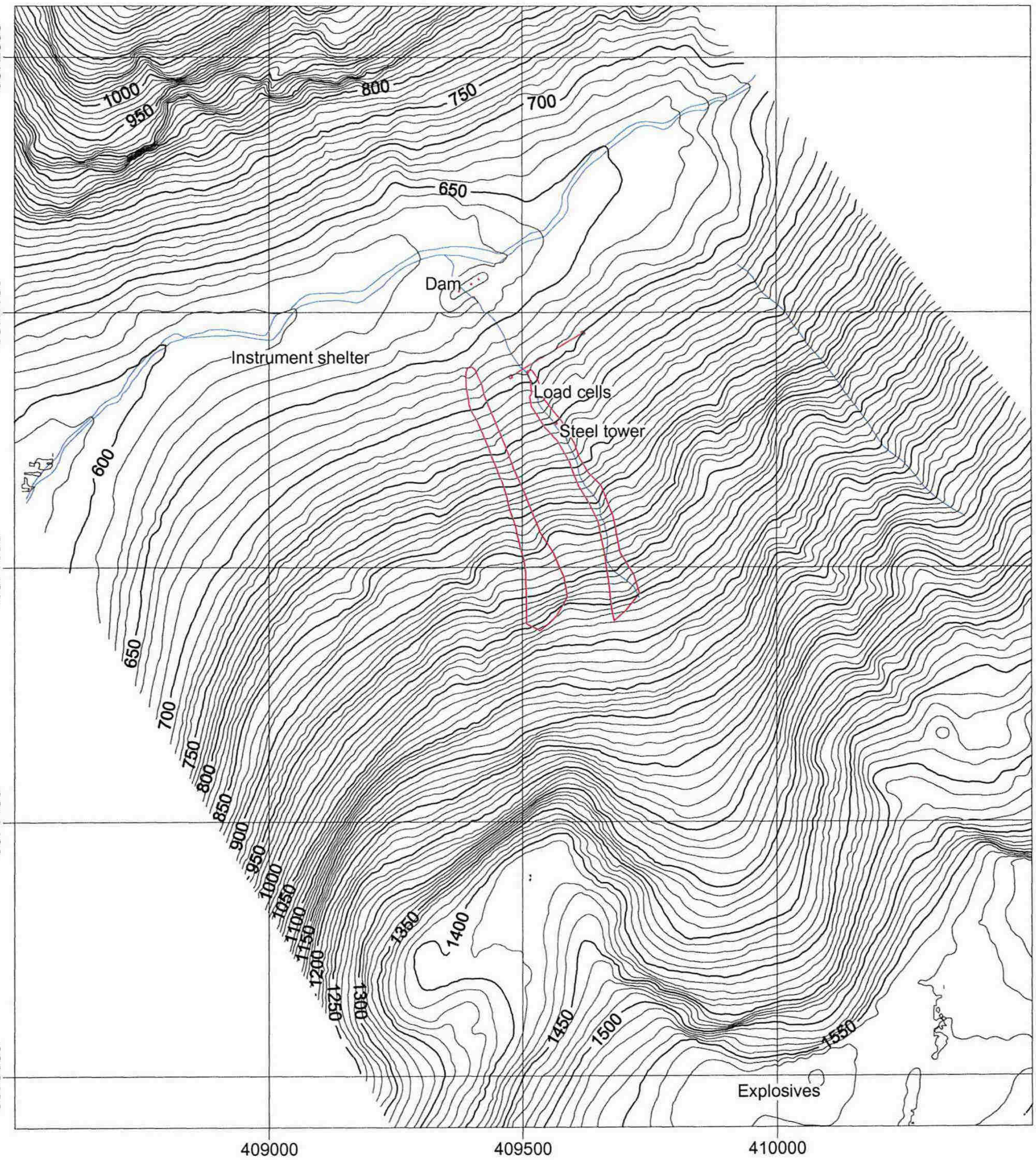
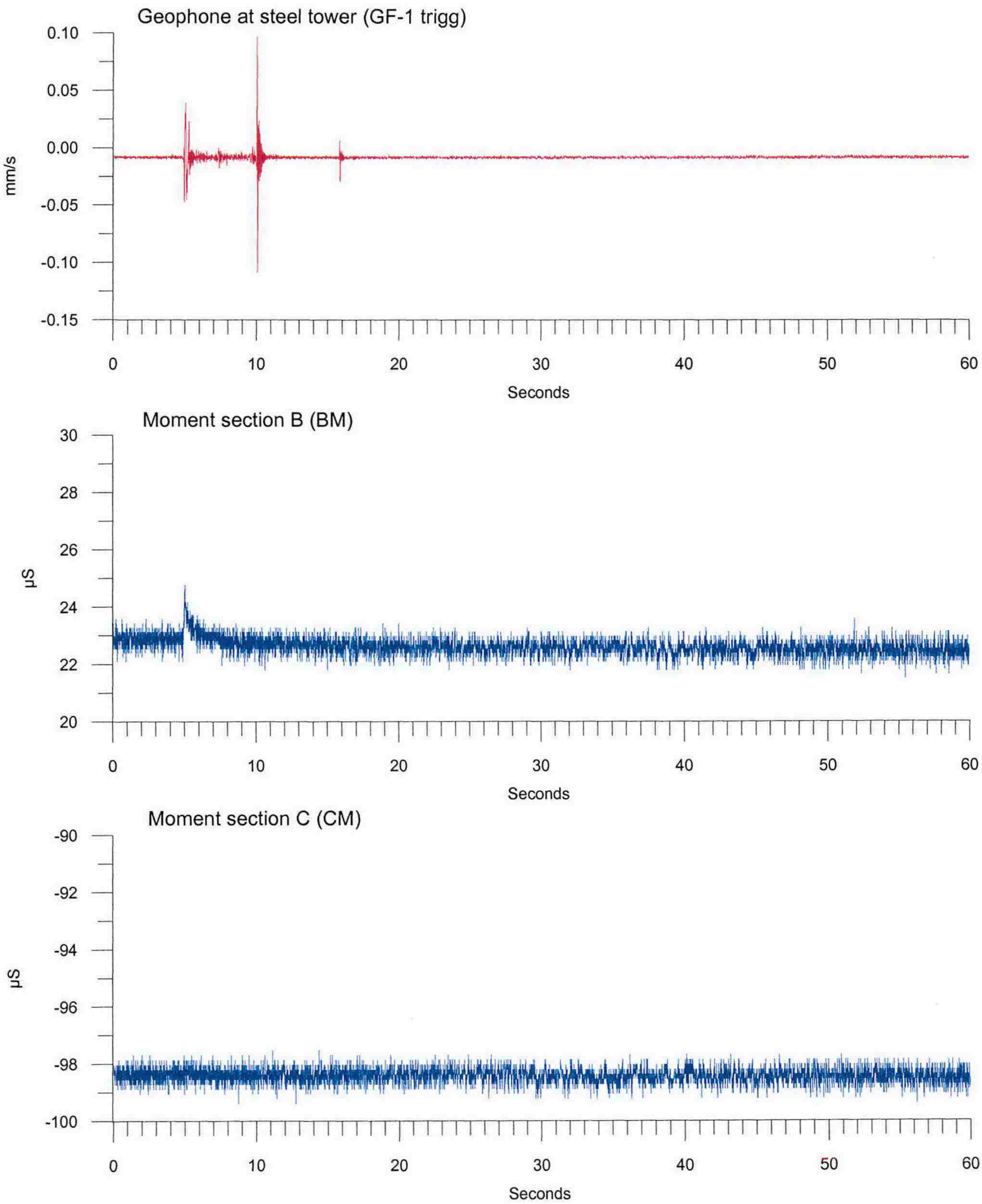
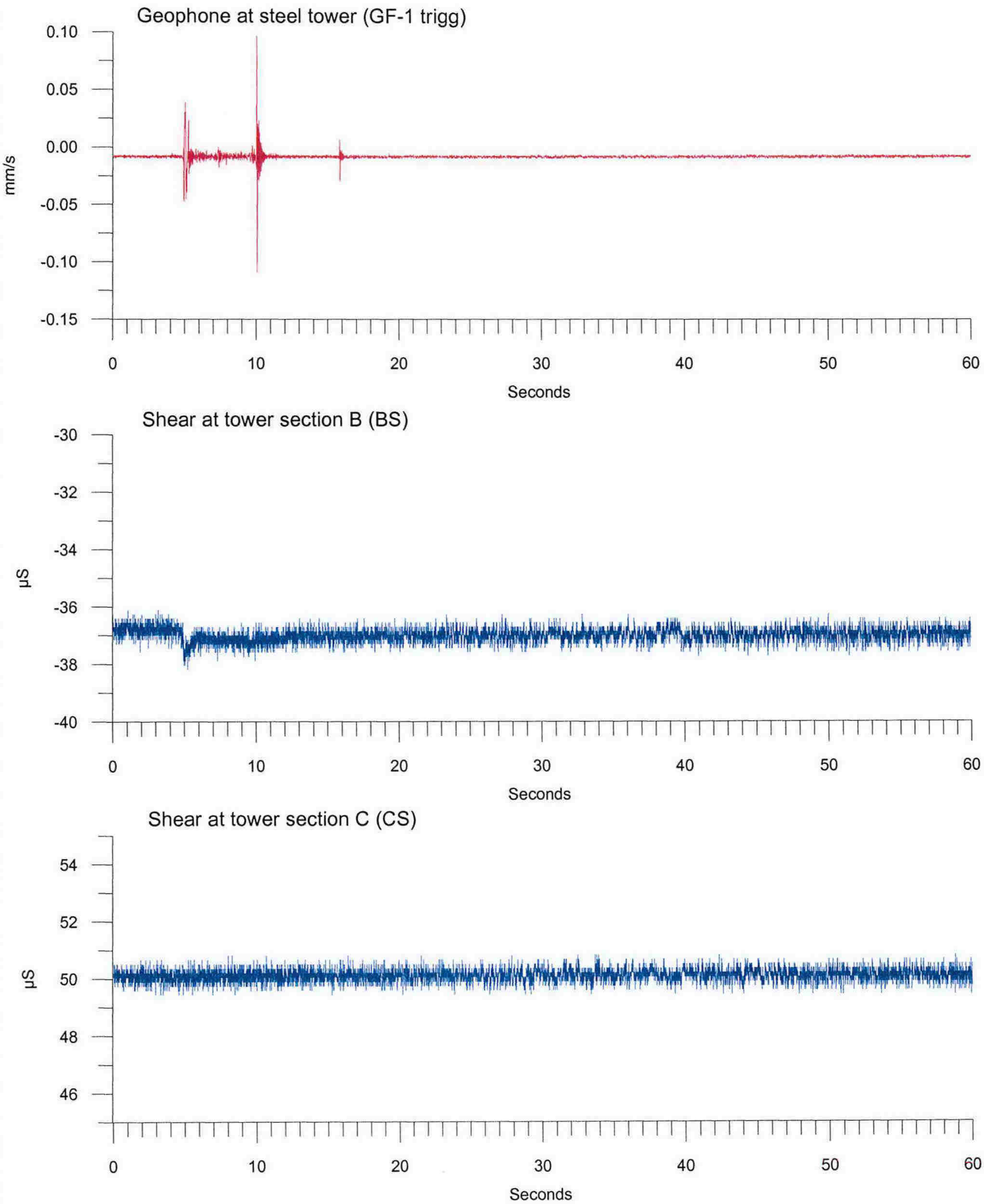


RYGGFONN	Report No. 581200-33	Figure No. 55.
Avalanche 1999-01-31	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 56.
Avalanche 1999-01-31	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 57.
Avalanche 1999-01-31	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

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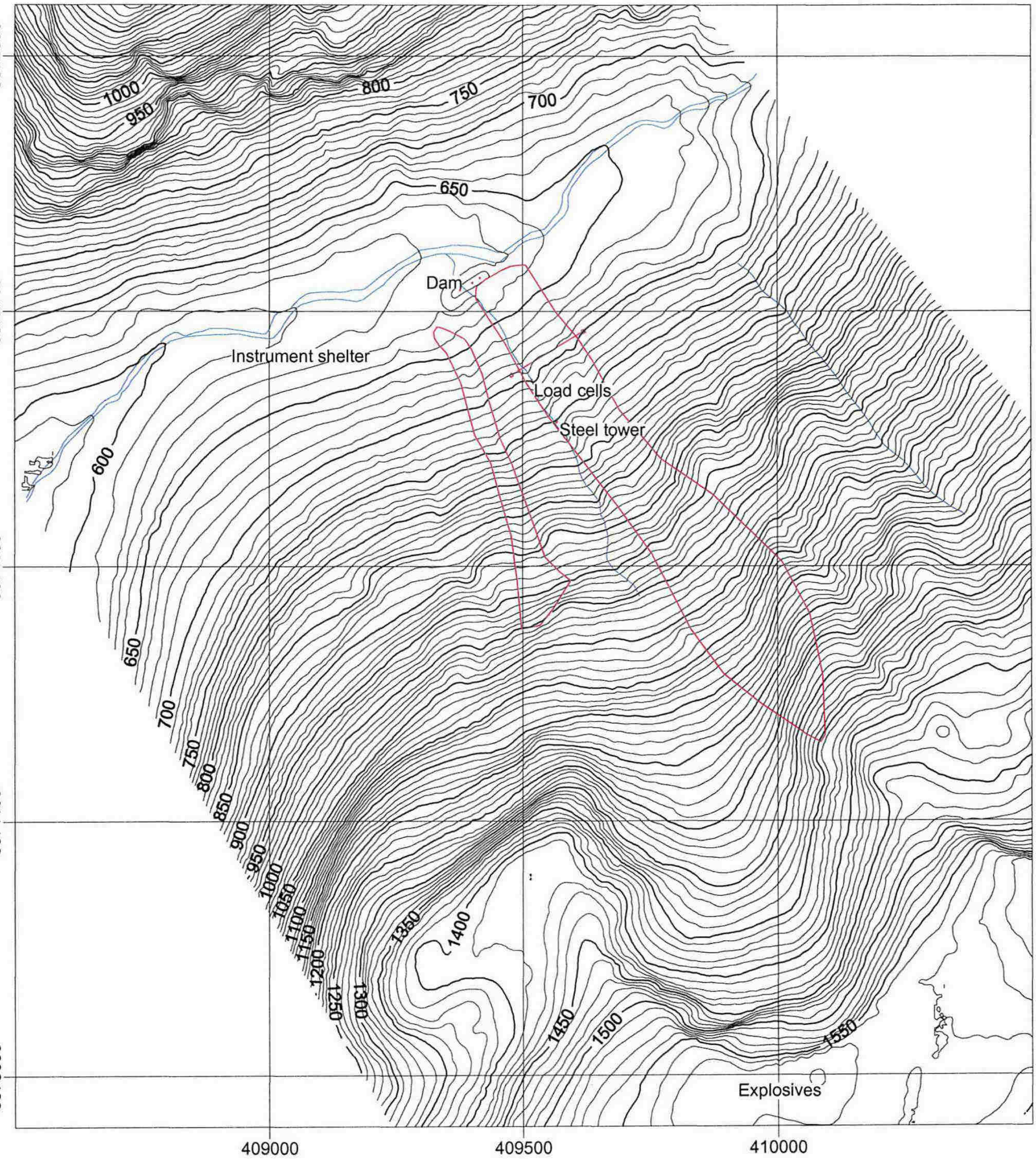
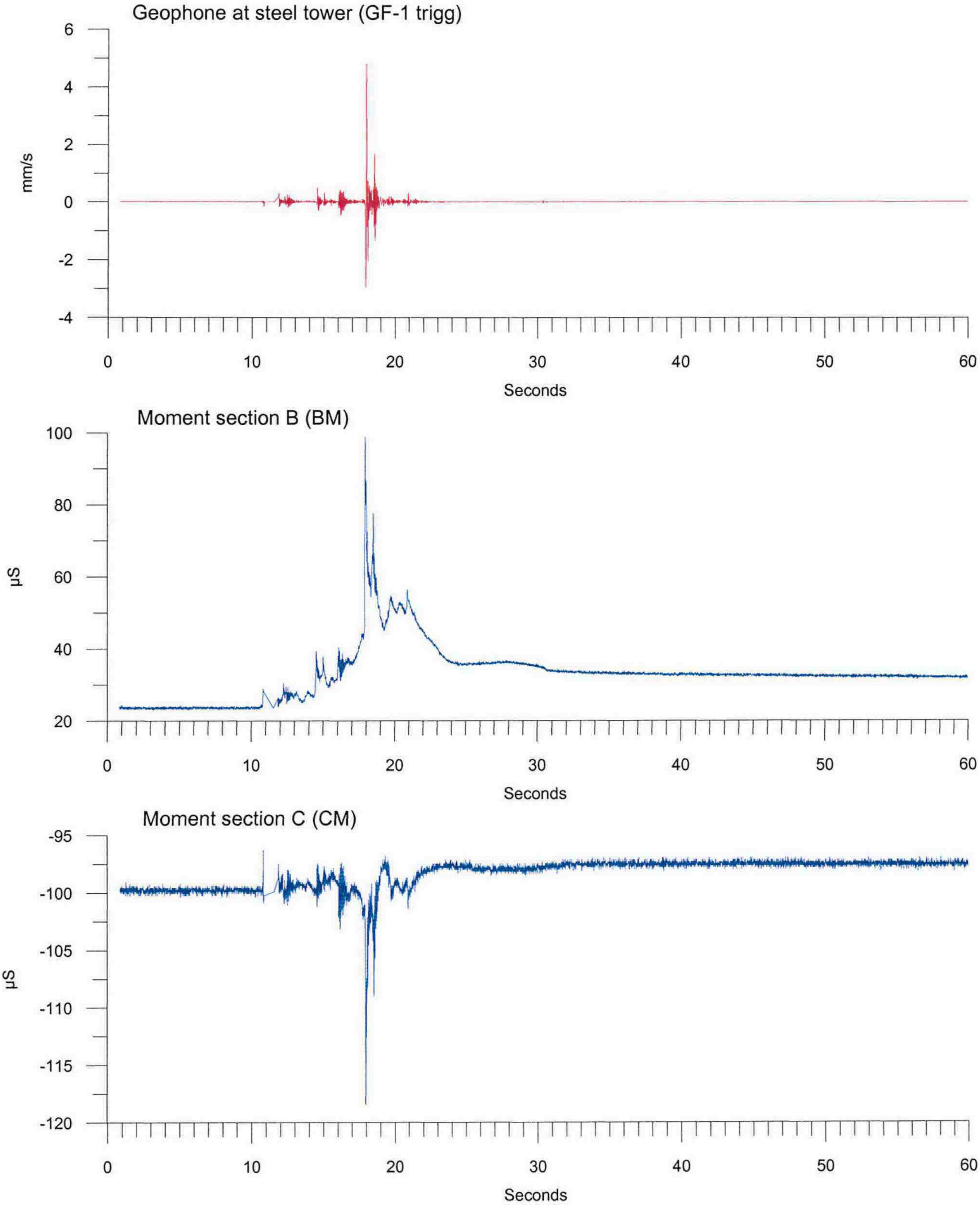
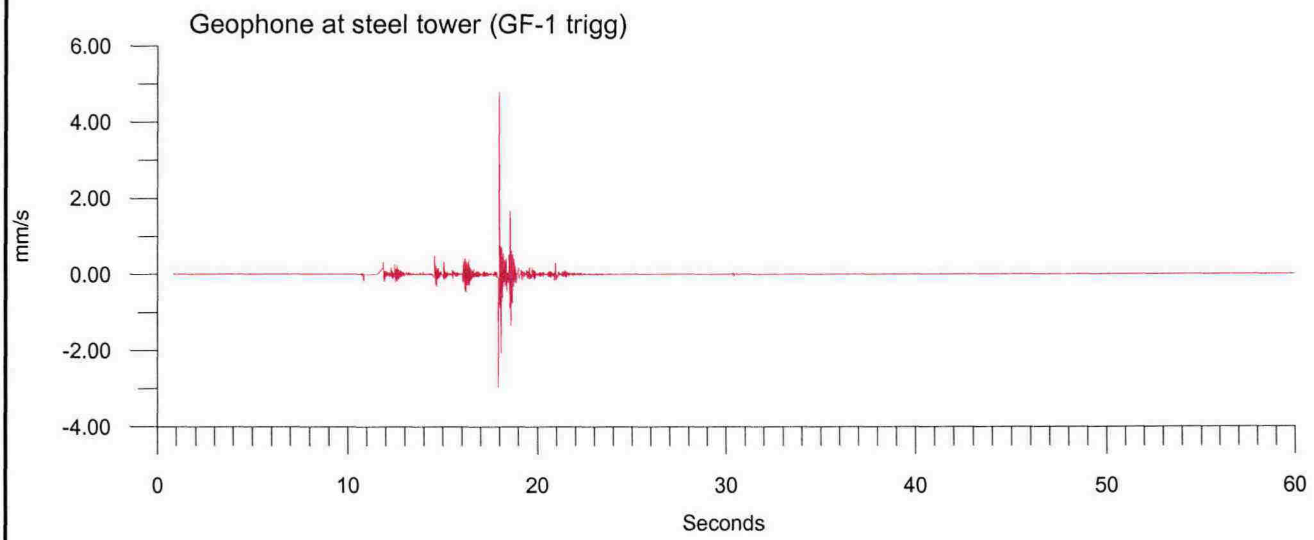
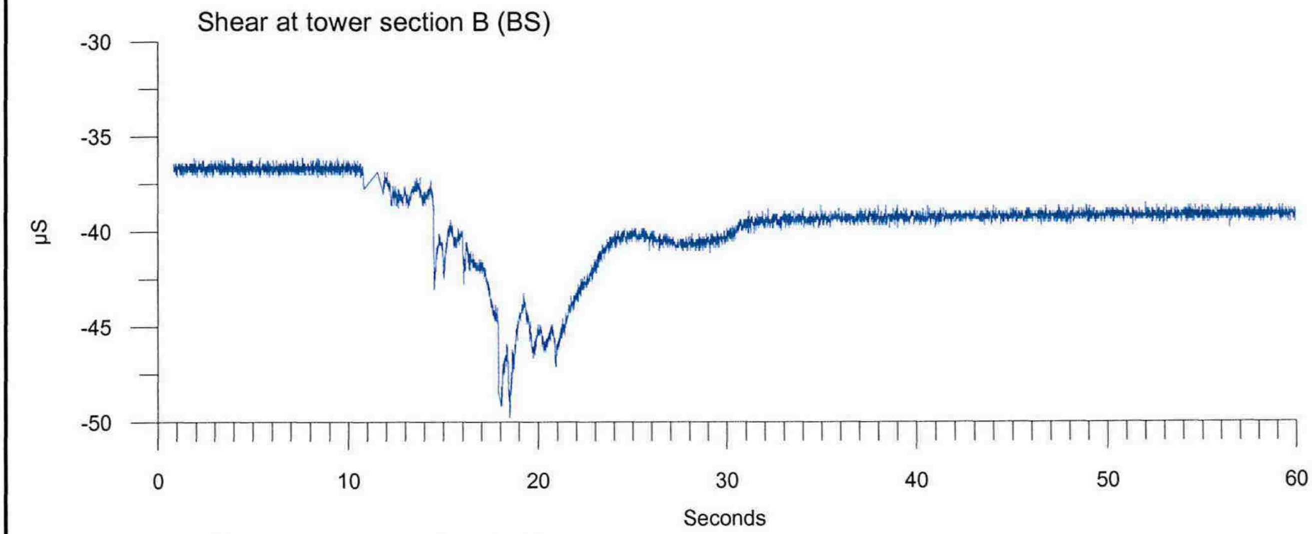


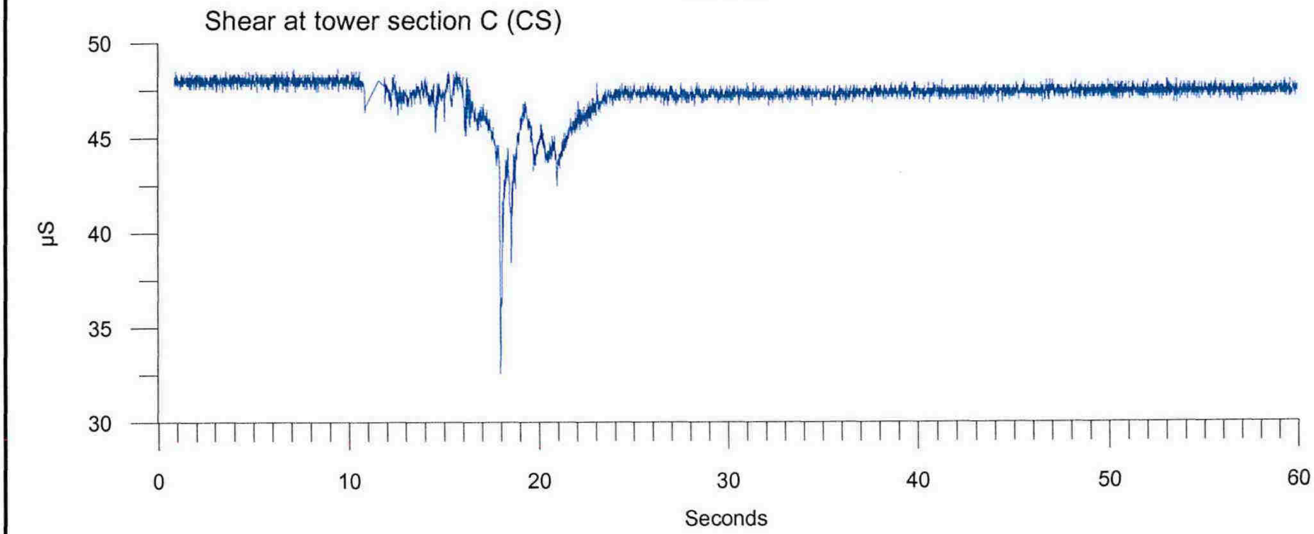
RYGGFONN	Report No. 581200-33	Figure No. 58.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



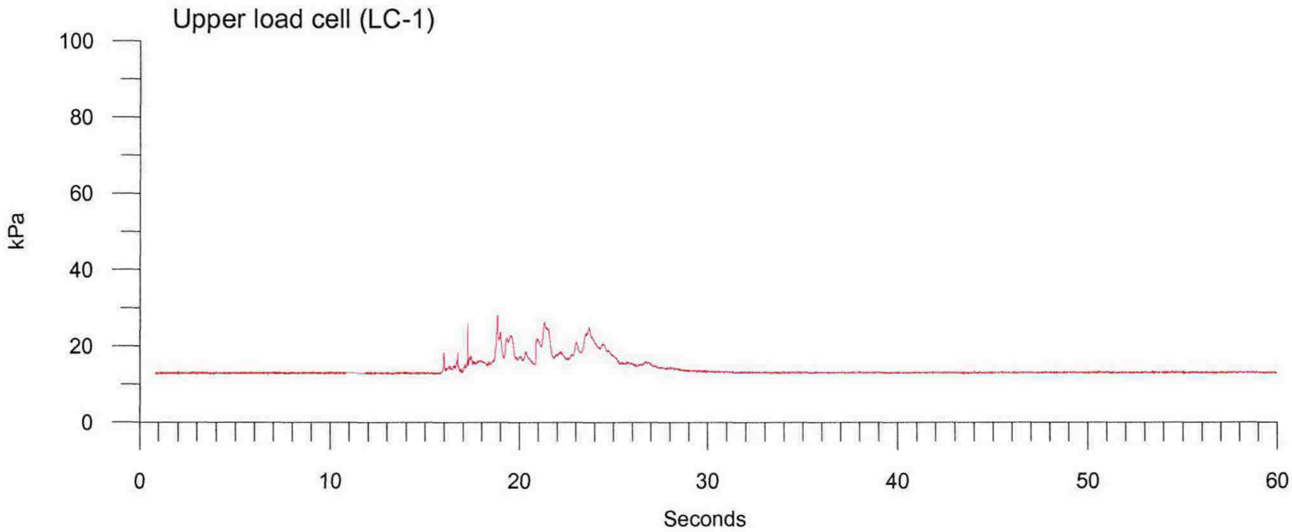
RYGGFONN	Report No. 581200-33	Figure No. 59.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI

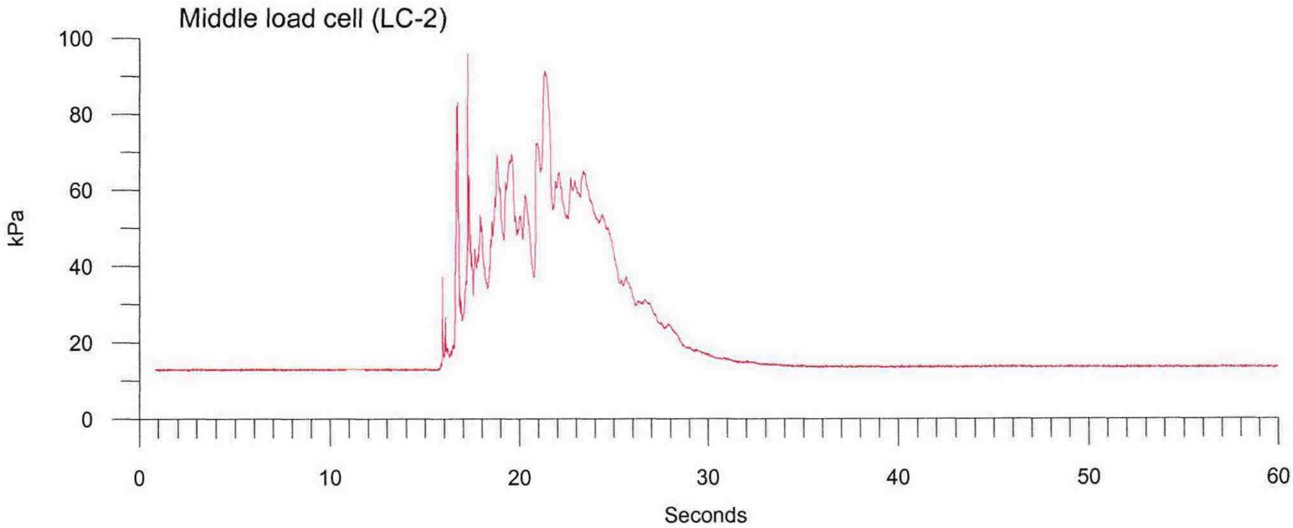


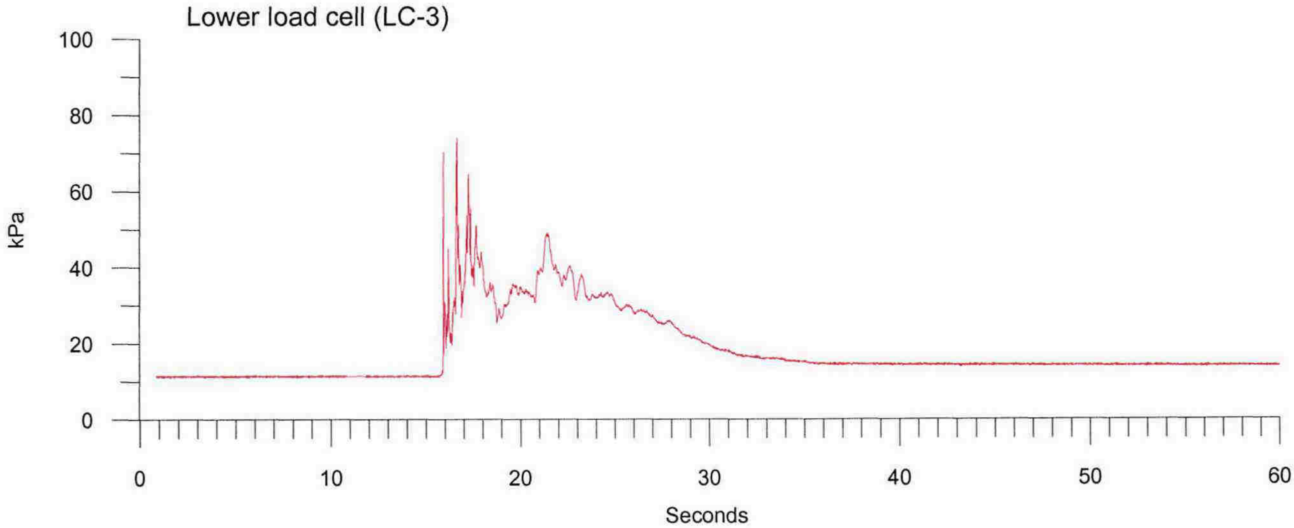




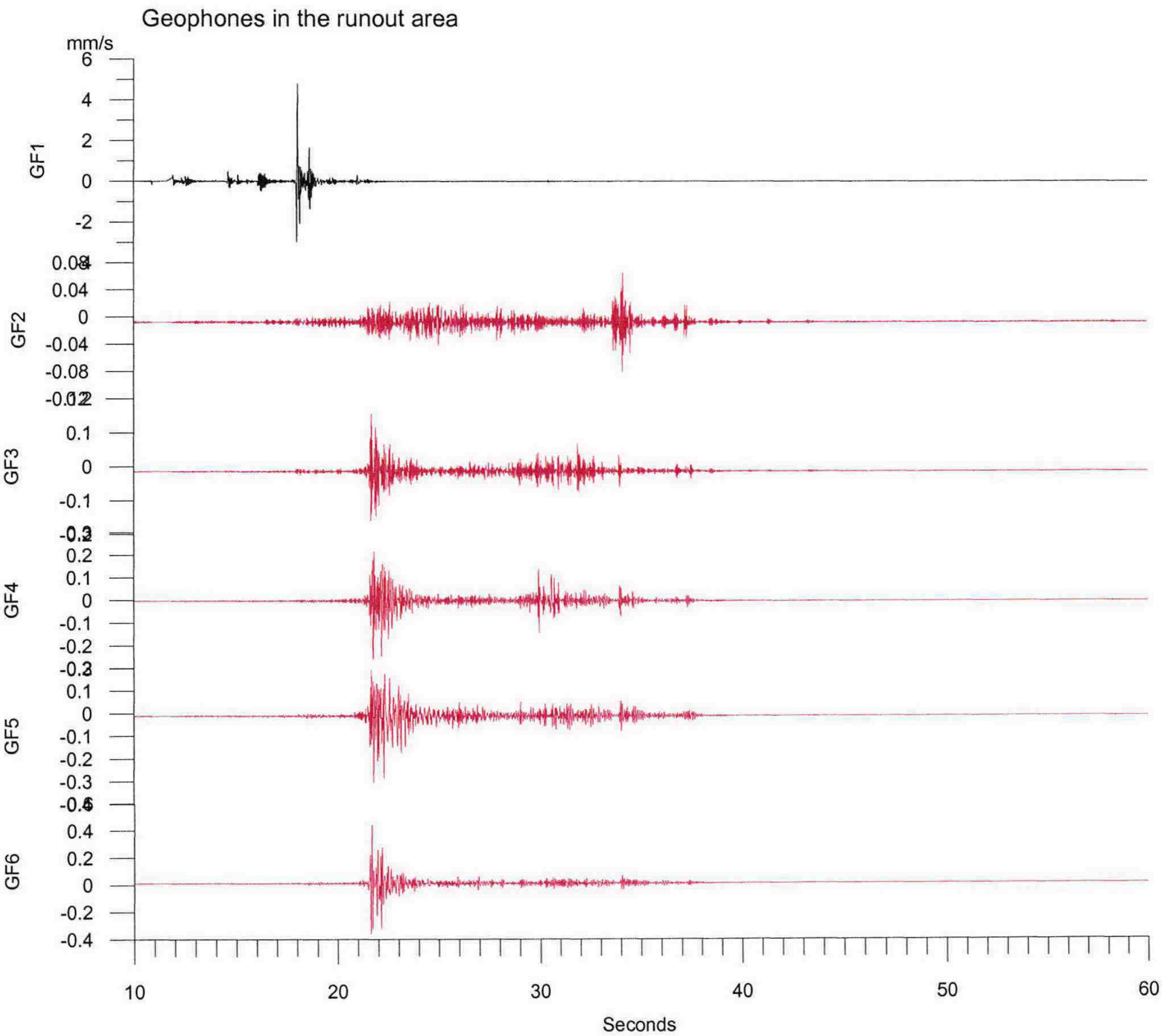
RYGGFONN	Report No. 581200-33	Figure No. 60.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



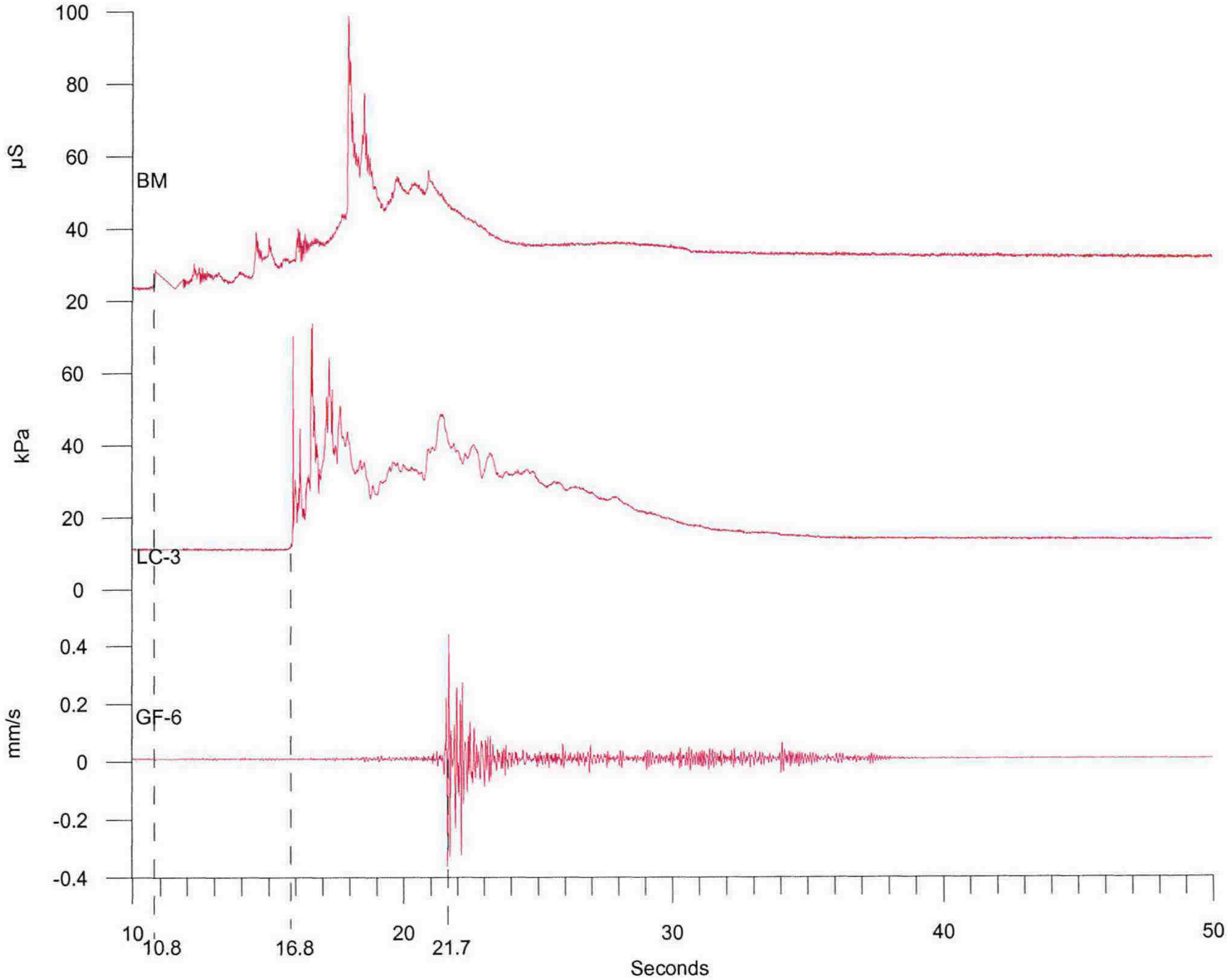




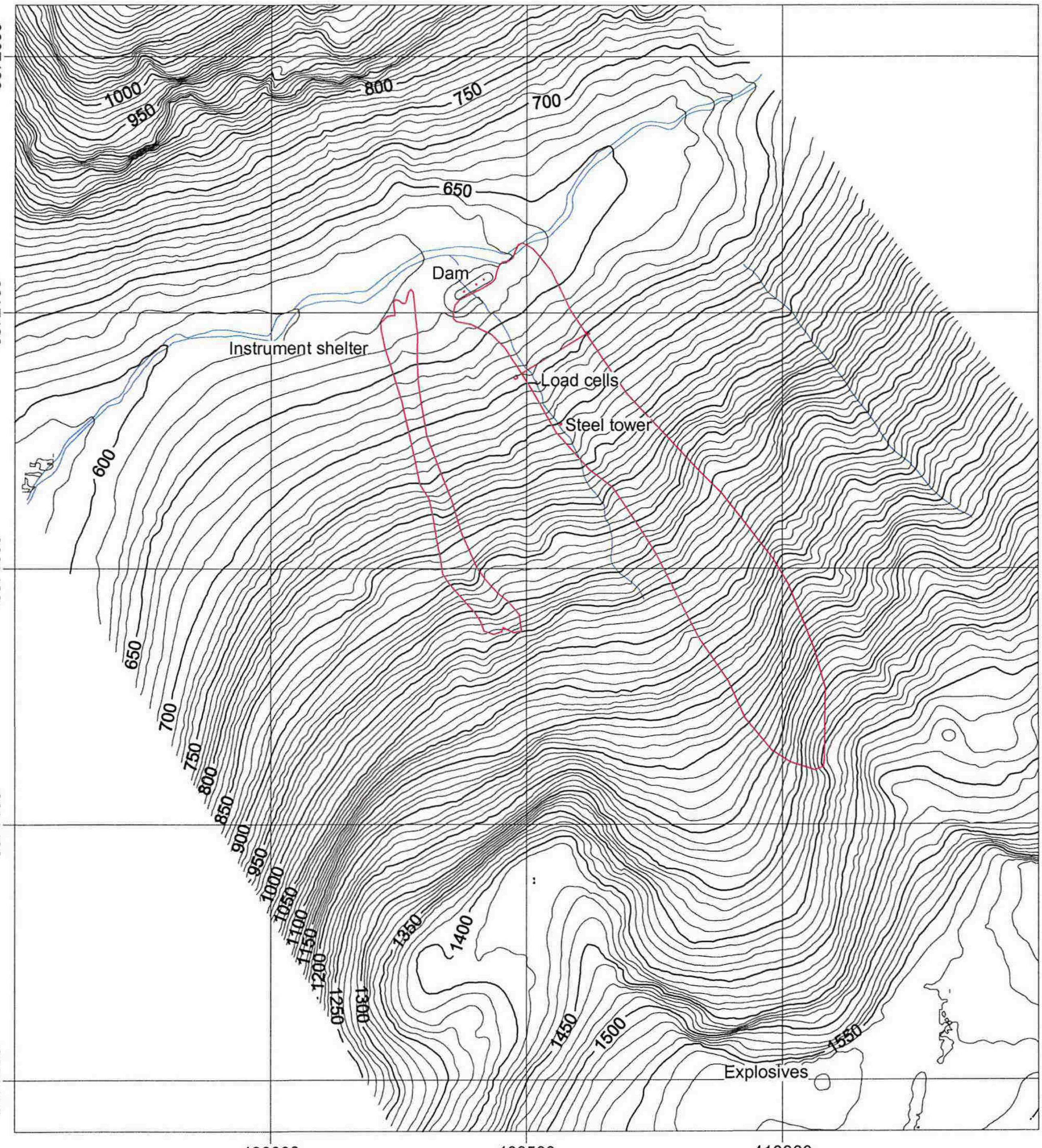
RYGGFONN	Report No. 581200-33	Figure No. 61.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



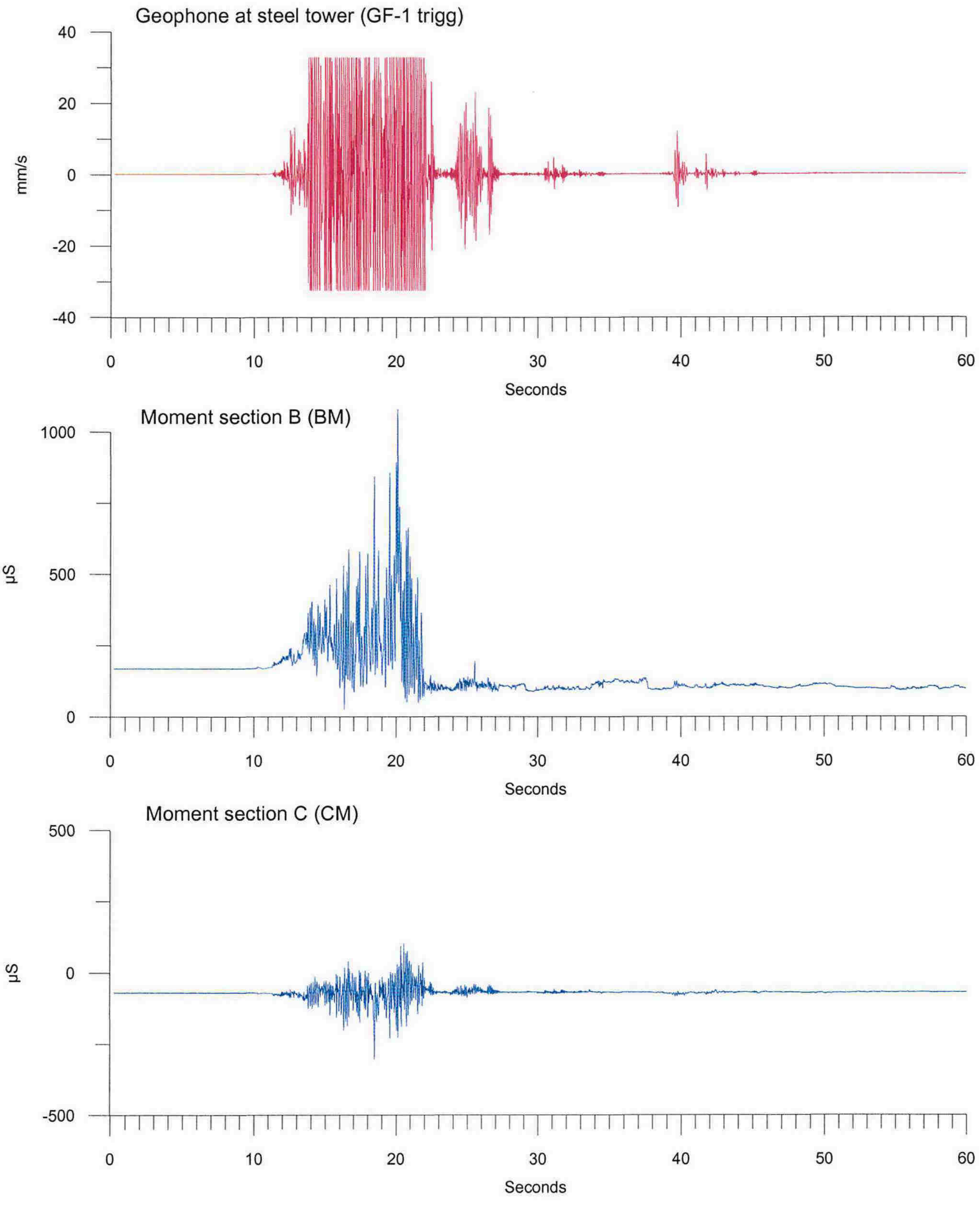
RYGGFONN	Report No. 581200-33	Figure No. 62.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



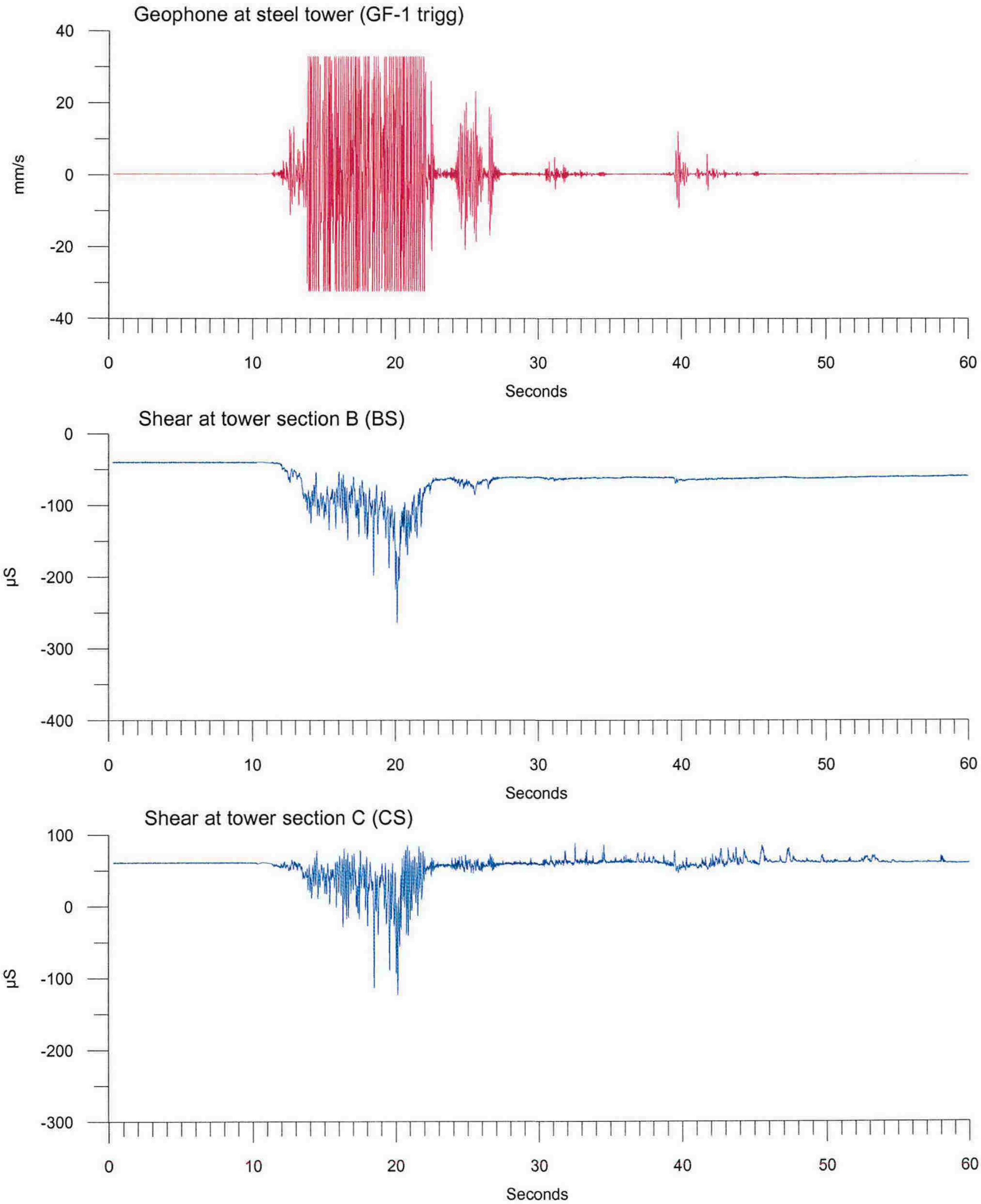
RYGGFONN	Report No. 581200-33	Figure No. 63.
Avalanche 1999-02-15	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



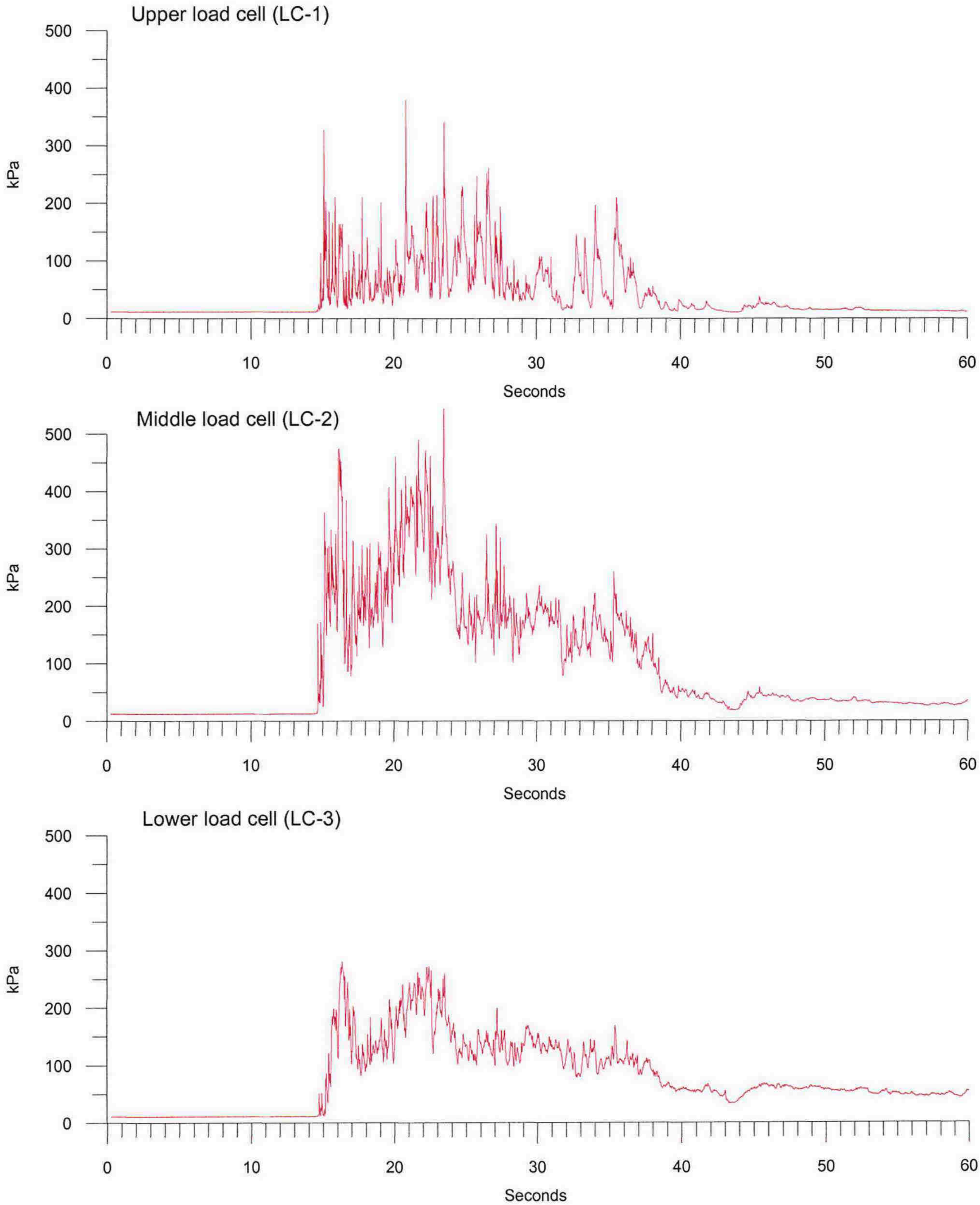
RYGGFONN	Report No. 581200-33	Figure No. 64.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



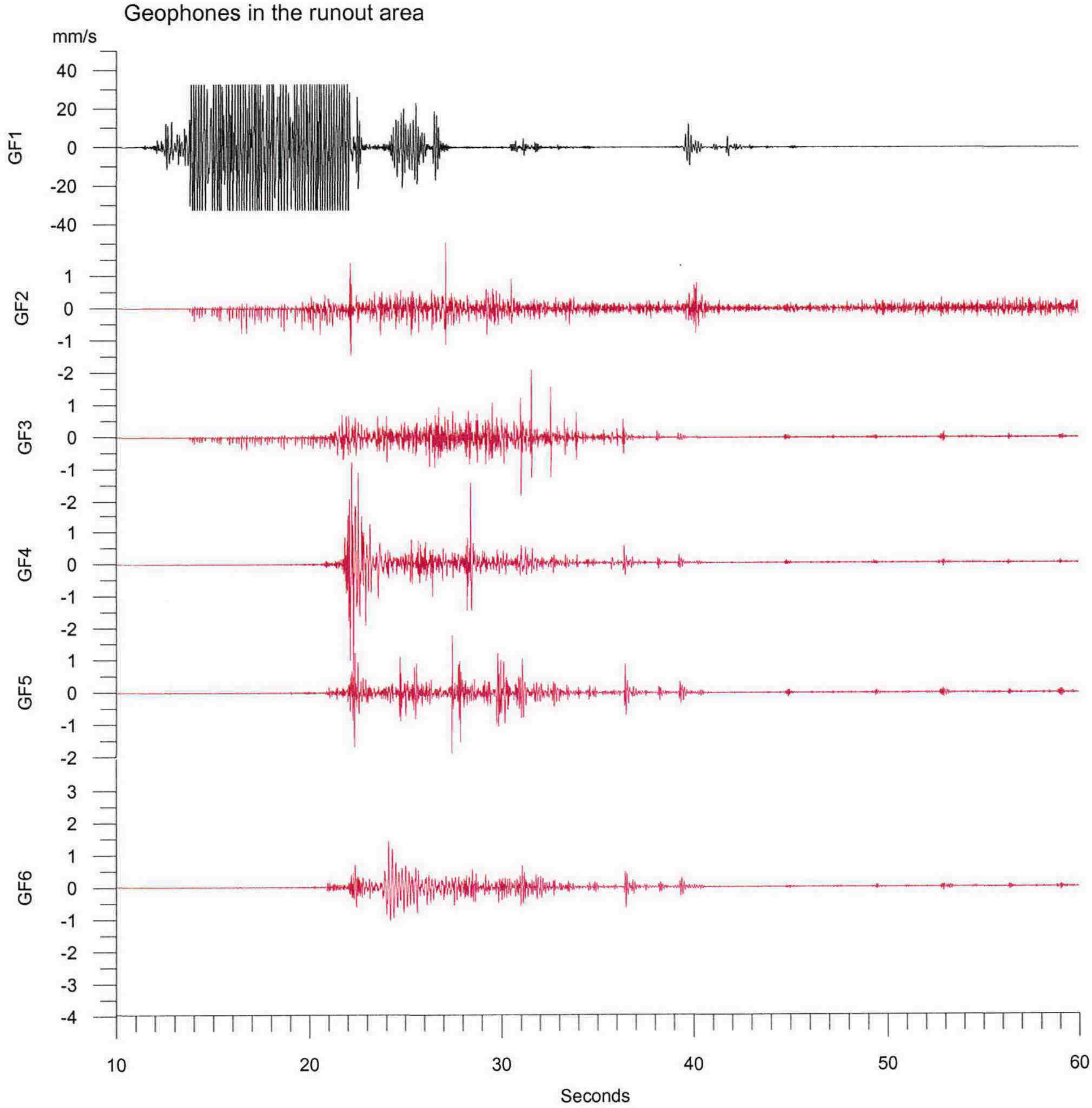
RYGGFONN	Report No. 581200-33	Figure No. 65.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



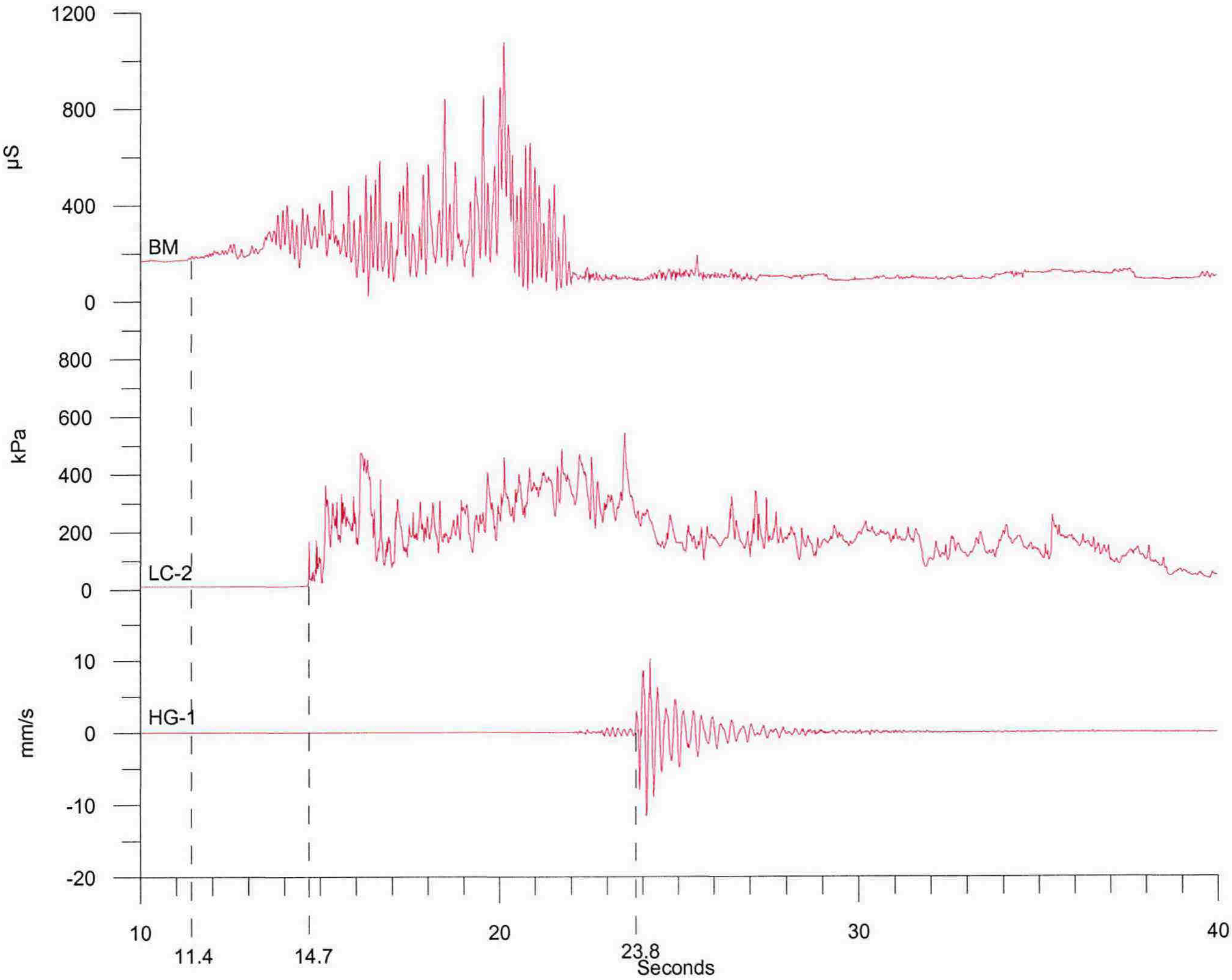
RYGGFONN	Report No. 581200-33	Figure No. 66.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



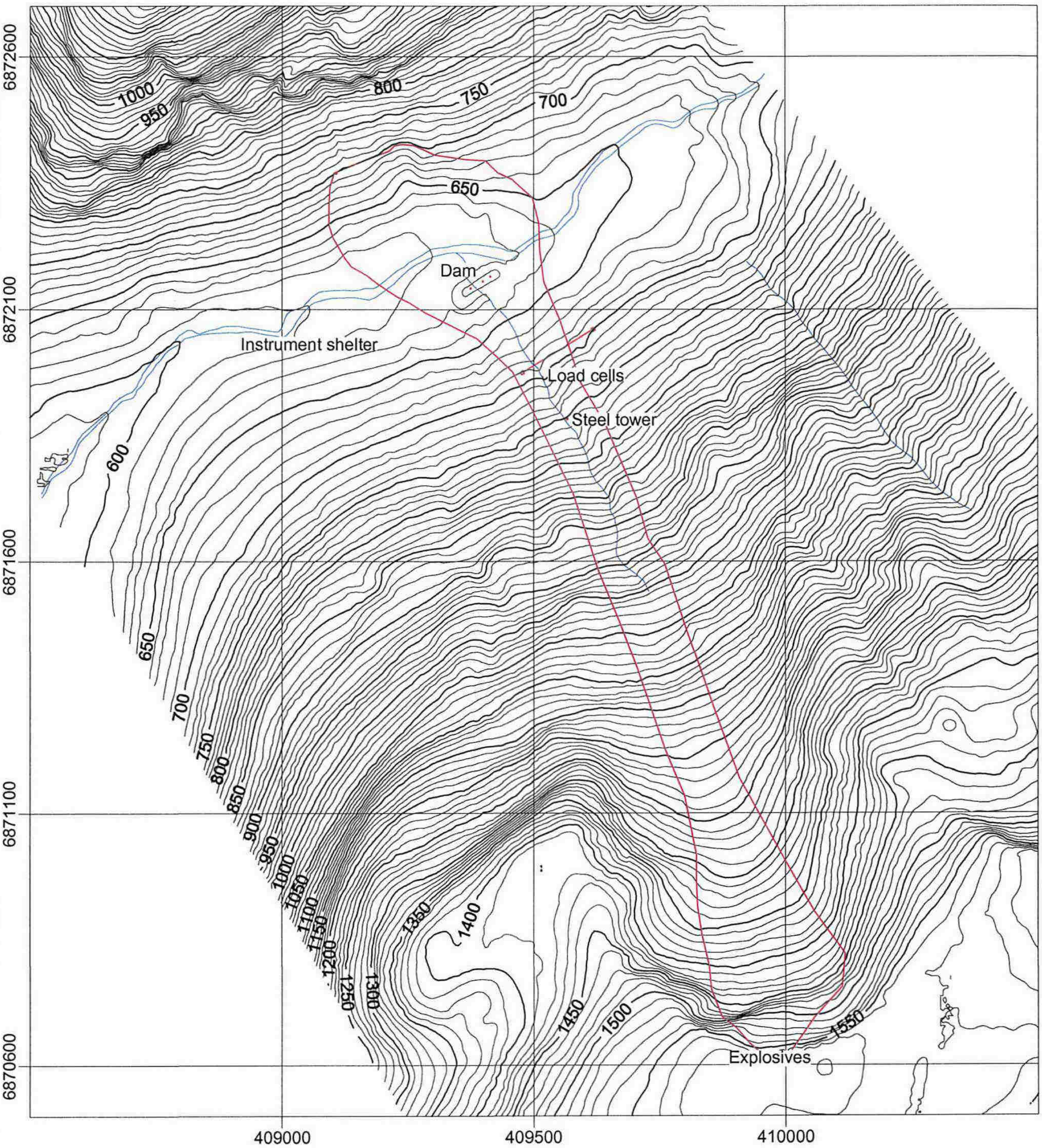
RYGGFONN	Report No. 581200-33	Figure No. 67.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 68.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI



RYGGFONN	Report No. 581200-33	Figure No. 69.
Avalanche 2000-01-11	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 70.
Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	

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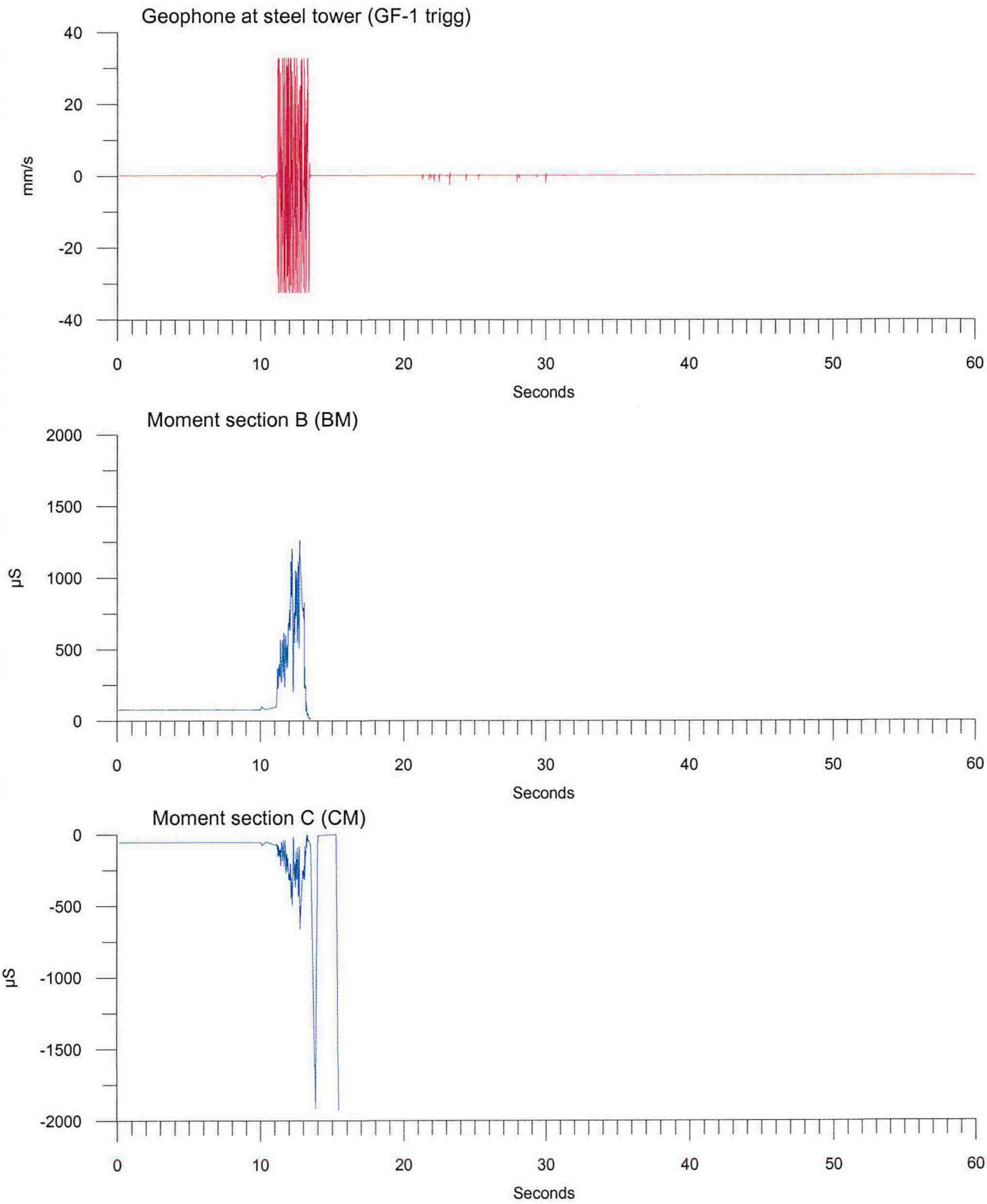
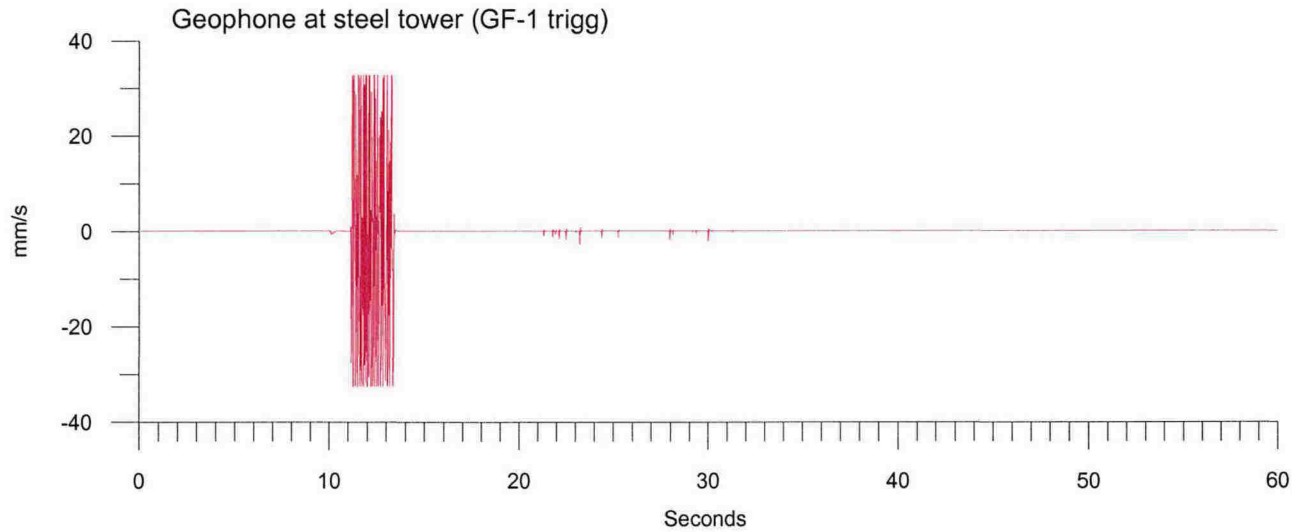
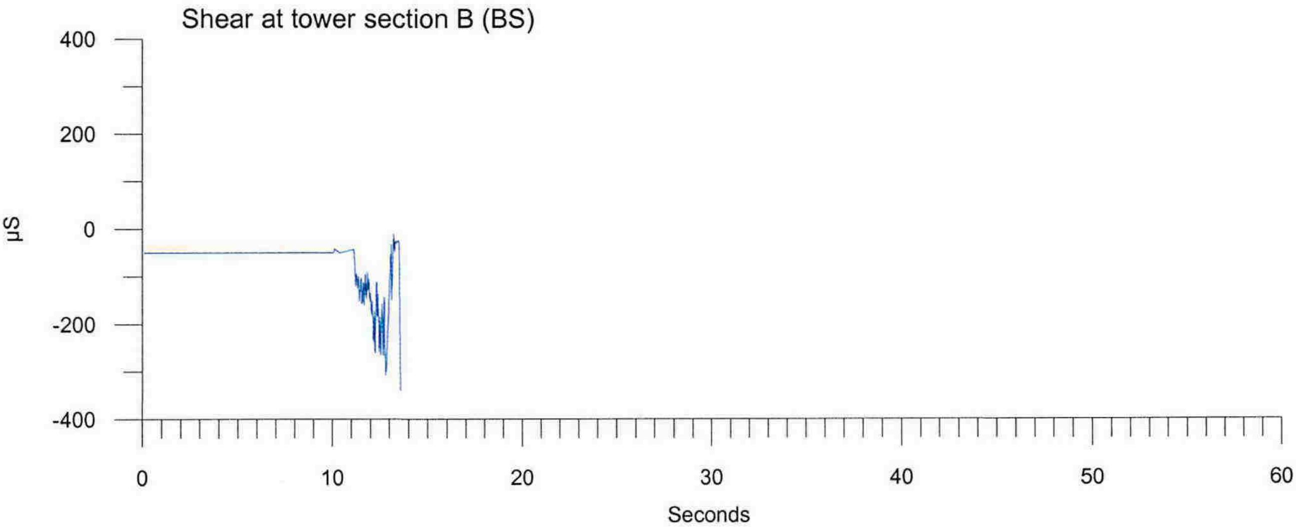
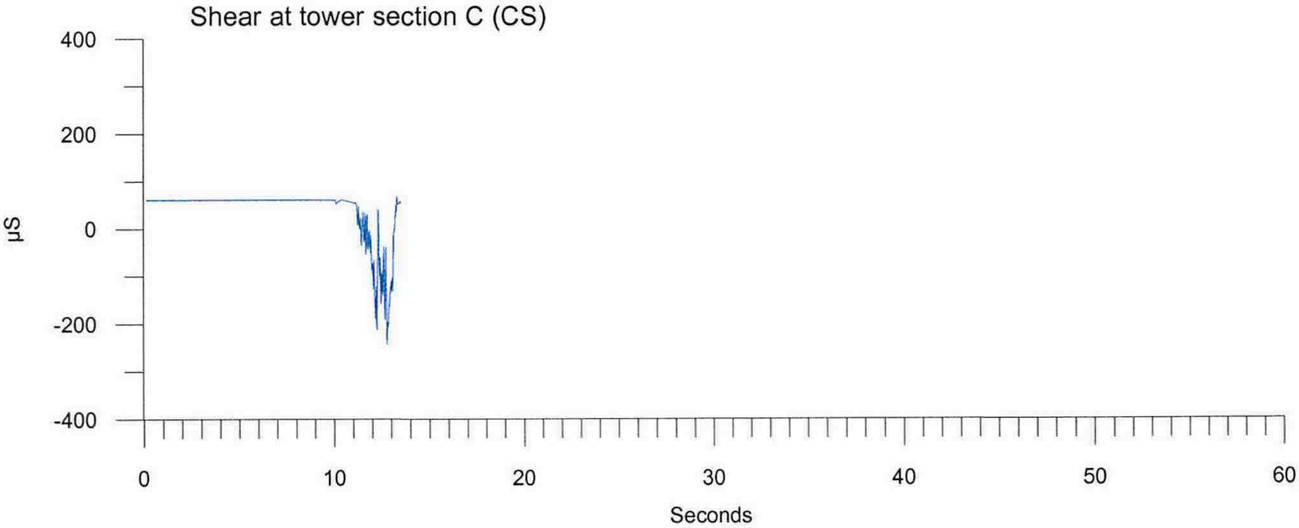


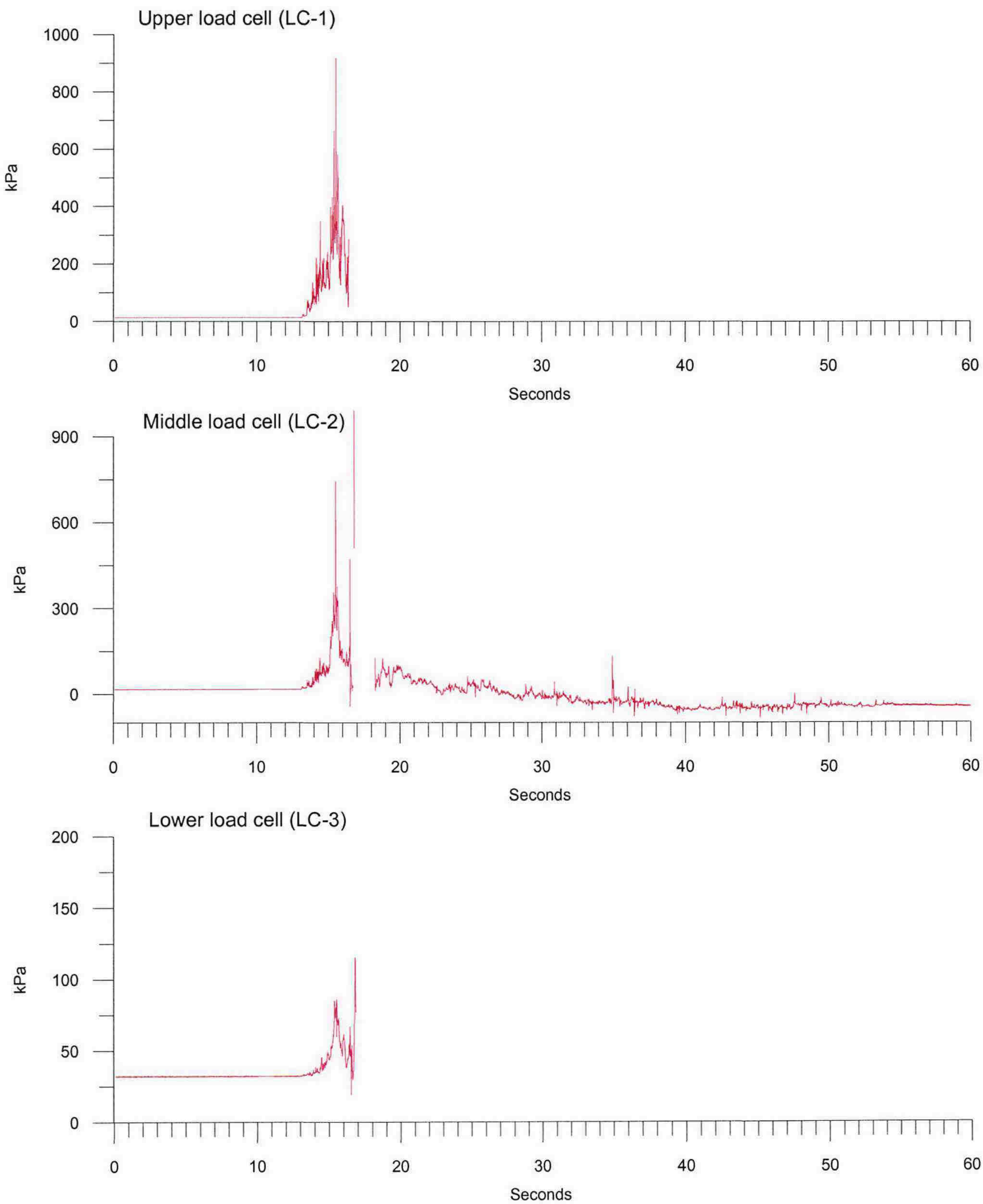
RYGGFONN	Report No. 581200-33	Figure No. 71.
Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



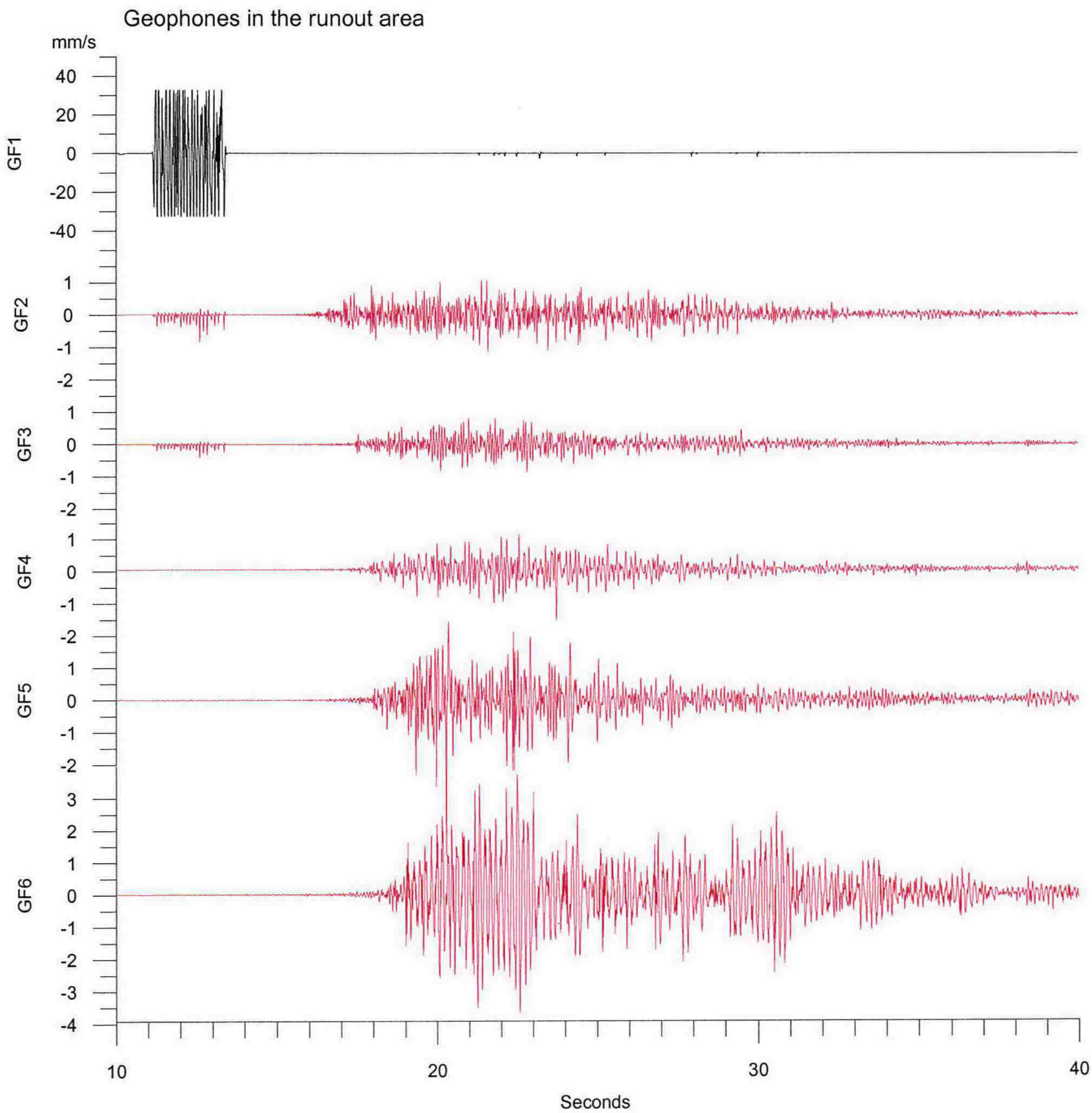




RYGGFONN	Report No. 581200-33	Figure No. 72.
Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 73.
Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
	Revised	NGI
	Approved	



RYGGFONN	Report No. 581200-33	Figure No. 74.
Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
	Revised	
	Approved	NGI

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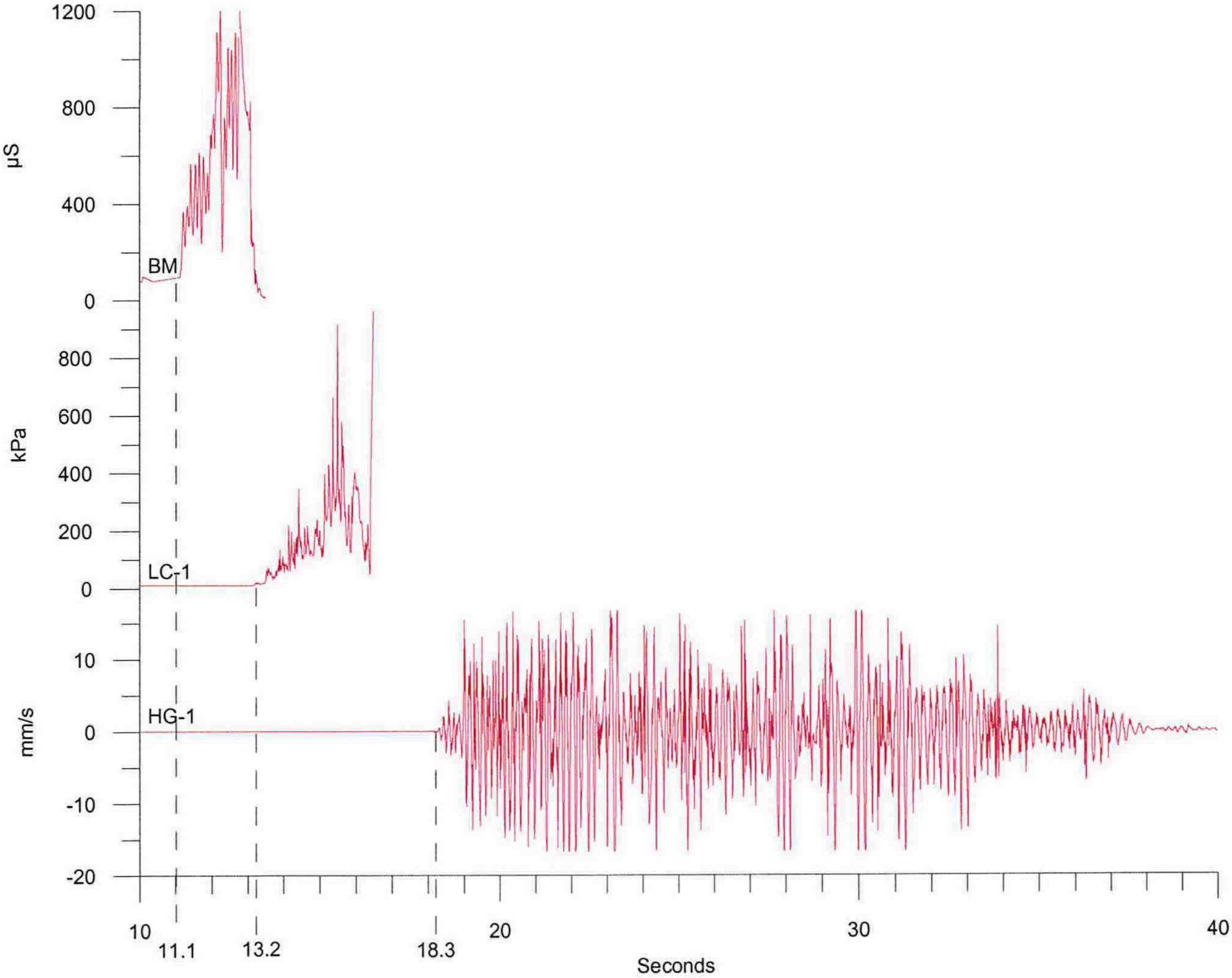

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Avalanche 2000-02-17	Drawn by KKr	Date 2001-11-01
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