Appendix 4.8

Line Source Response along the WIL Alignment

Description of the Measurements and Ground Vibration Propagation Model

As there are many sensitive receivers along an alignment, it is not practicable to perform a PSR measurement at each receiver location. Alternately, PSR measurements were performed at the most sensitive locations along West Island Line, such as the University of Hong Kong, the Chinese Rhenish Church and at some of the hospital, and at other locations that provide representative data for the geologic formations along the alignment. The Point Source Response (PSR) is determined from impacting in a borehole (borehole impact test), as shown schematically in Figure 3 for underground source (alignment) locations, and by impacting on the surface (surface impact test) as shown schematically in Figure 4 for surface source (alignment) locations. Locations of impact boreholes are given in Drawing A4.1-A4.5. There were 16 boreholes in total, each borehole was impacted at surface (except D103) and two different impact depths.

Force impact testing was performed during the time period of 21 October 2005 to 26 January 2006 at surface and two depths in most of the WIL boreholes. Combinations of boreholes location, impact depths, placement of accelerometers, dates of testing and other pertinent information are given in Table 3.

Taken together, the WIL borehole impact tests were performed in rock, in soil and close to the rock head both on the soil side and the rock side, with receiver vibration data taken at many setback distances. Close inspection of the measurement data indicated that it would not always be accurate or conservative to apply measurement data taken at a receiver location to predict vibration propagation at that particular location. At some geologically and structurally similar locations, receiver levels were higher at one location than at the other. And finally, multiple transmission paths from tunnel to receiver, i.e., through soil, or rock or along the soil rock interface, as shown in Figure 2, were not always captured by measurements at every receiver.

This measurement data has been organised so that the differing geological conditions at receivers along the alignment, namely, the setback of the receiver from the alignment, the depth of the tunnel, and the depth of the receiver-building basement can be input. For the given input conditions, the overall PSR is extrapolated from the borehole impact database with respect to the setback, and source and receiver depth. The Line Source Response (LSR) is then determined by (numerical) incoherent integration of the PSR along the length of the train centred on the receiver.

$$LSR(s,d,f) = 10\log\left[\int_{-l/2}^{l/2}\left[10^{PSR\left[\sqrt{d^2+s^2+y^2},\,f\right]/20}\right]^2 dy\right]$$

where *s* = perpendicular setback
d = depth to top of rail
l = train length

1) The PSR is numerically interpolated between setbacks to create contour surface in frequency and setback.
2) The integral is determined for a given frequency, setback and depth using numerical integration.

An example of the determination of the LSR from the PSR obtained at BH 103 at a depth of 21m (Figure 25) is given in Figure 26 at data measurement setbacks. A direct comparison of the PSR and LSR at two setback is given in Figure 27.

All buildings along the alignment were assumed to have foundations on piles or other foundings that extend down into the rock. Thus, each receiver is assumed to be impacted by multiple vibration paths. For the case of the tunnel situated near the deeper impact depth, the LSR is interpolated from the two nearest borehole's deeper depth PSRs. For the case of the tunnel situated in between the two impact depth, the LSR is interpolated from two borehole and two impact depth PSRs.

Instrumentation

Vibration measurements were recorded and analysed with 1) Teac RT130 & 135 DAT tape recorders, Serial #512826 & #731107, and 2) a B&K Pulse 22 Channel Spectrum Analyser, Model 3560B, Serial #2382079. Sensor type and power supplies for the vibration receivers, shown in Table 1. Two WIA 222 conditioning amplifiers (Units # 5 and 6) were used for second stage signal amplification. Vibration calibration was performed with an IMI Vibration Calibrator model 699A02, serial #376.

The vacuum assisted impact tool (WAMMY) is shown in Photo 1 attached to the top of the drill string for downhole impacting. It was manufactured by Wilson, Ihrig & Associates, Inc. (WIA) of Oakland CA USA. This tool drops a 20 kg steel slug thru 1.2 m to provide an impact force to the ground. A vacuum system with a flow reverser: 1) augments the impact by a minimum factor of 1.2 by providing a back pressure in the downward direction; and 2) lifts the metal slug to the top position by reversing the back pressure to the up direction just after impact, which also prevents double or multiple bounces. A strain gauge is built into its base in order to determine the imparted force when surface impacting. The WIA strain gauge amplifier, Model # 140 Unit #3, or Dual Channel Model #143 provides first stage amplification and power supply.

For borehole impact tests, where the impact hammer is attached to the top of the drill string and the load is imparted to the ground at the bottom of the borehole, a impact load measure the imparted force at the point of impact with the ground. The strain gauge amplification and power supply is the same as that for the impact hammer.

Measurement Data Analysis

Between 20 and 40 hammer blows were time averaged for signal to noise enhancement for each measurement set with square windowing applied to the force and modified (quarter sine wave) square windowing applied to the vibration measured at each setback. The transfer function (vibration divided by force or point source response (PSR)) narrow band spectrum of the result was determined from 0 Hz to 500 Hz using an 800 line Fast Fourier Transformation, not including aliasing lines. The narrow band PSR was the summed to 1/3 octave bands for determination of the LSR.

Indicative Results

Figure 5-25 gives the Point Source Response for various impact boreholes used to calculate LSR for the receiver. The LSR for each receiver is obtained by extrapolating the PSR at the receiver from that determined from nearest adjacent impact borehole tests performed on each side of the receiver. Extrapolation occurs but along the alignment and with depth, as practicable.

References

1. Nelson, J.T. and H.J. Saurenman, "Procedures for Prediction of Ground-Borne Noise and Vibration from Rail Transit Trains", May 1986. Preliminary Draft prepared by Wilson, Ihrig & Associates, Inc., Oakland, CA for the Transportation Systems Centre of the US Department of Transportation.

Tables

Table 1 Vibration Receiver Equipment Used for the LSR Measurements

Accelerometer/ Geophone	Charge Amp/ Preamp	Number of Units
Geospace Digiphone (Geophone)	WIA Geophone Preamplifier	8
Endevco 7701A 1000 Accelerometre	WIA 112L Charge Amplifier	4
Wilcoxon Model 731A Seismic Accelerometre	Wilcoxon P31 current power supply	3

Table 2 Other Instruments Used in the Performance of the Impact Tests

Instrument	Manufacturer / Model No.	Number of Units
22-Channel Spectrum Analyser,	B&K Pulse, Model 3560D,	1
2-Channel Conditioning Amplifier	WIA Type 222	2
4-channel Conditioning Amplifier	B&K Nexus, Type 2693 A 014	2
8-channel DAT Recorder	Teac RD135T	1
8-channel DAT Recorder	Teac RD130TE	1
20 kg vacuum assisted impact hammed with load cell	WIA	1
Strain Gauge Preamplifier	WIA	1

Table 3 Borehole Impact Test Information

Borehole No.	Location	Impact Depth (m)	Measurement Date	Sensors No.	Dist (m)
D002	Hongway Garden to New Market street	0, 19.6 and 33.7	18/12/05 & 20/12/05	1	5
				2	14
				3	25
				4	34
				5	45
				6	55
				7	73
D012	Sutherland Street	0, 18 and 41.4	19/12/05 & 22/12/05	1	5
				2	15
				3	30
				4	40
				5	46
				6	60
				7	70
D018	Li Sing Street Playground	0, 14.9 and 39.8	26/10/05 & 01/11/05	1	5
				2	15
				3	25
				4	32
				5	45
				6	55
				7	70
D134	Tsz Mi Alley	0, 11.5 and 24.2	24/01/06 & 26/01/06	1	5
				2	10
				3	15
				4	25
				5	35
				6	45
				7	60
D024	Tsan Yuk Hospital	0, 30.1 and 50.9	27/10/05 & 31/10/05	1	6.5
				2	16.5
				3	26.5
				4	36.5
				5	46.5
				6	56.5
				7	66.5
D028	The Prince Philip Hospital	0, 20.3 and 44.3	11/11/05 & 17/11/05	1	9
				2	18
				3	30
				4	45
				5	60
				6	6.8
				7	12.9
				8	20.5
				9	25.7
				10	32.8
				11	36.7
D032	Kwok Hing Lane	0, 36.3 and 57.3	23/11/05 & 30/11/05	1	10
				2	16.1
				3	24.9
				4	34.3
				5	44
				6	56.8
				7	68.7
D047	St. Stephen’s Lane	0, 71.7 and 95.6	25/11/05 & 29/11/05	1	5.8
				2	11.7
				3	21.2
				4	35
				5	46.7
				6	58.3
				7	70

Table 3 Borehole Impact Test Information (Con't)

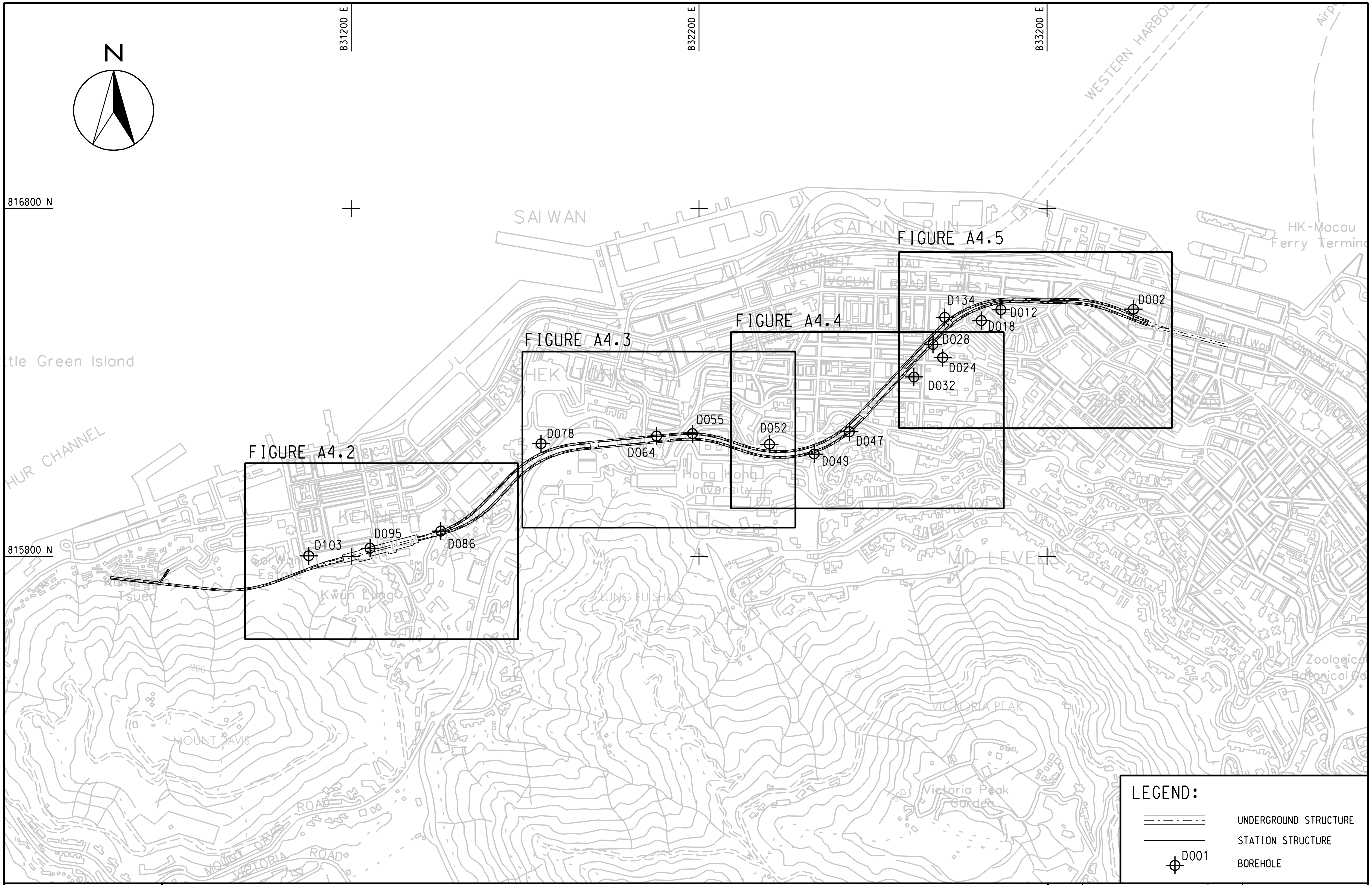
Borehole No.	Location	Impact Depth (m)	Measurement Date	Sensors No.	Distance (m)
D049	Chinese Rhenish Church	0, 60.4 and 87.8	8/12/05 & 13/12/05	1	5.5
				2	16.5
				3	27.5
				4	38.5
				5	49.5
				6	64.9
				7	75.9
D052	TT Tsui building of the University of Hong Kong	0, 30.5 and 84.9	30/12/05 & 15/01/06	1	5.5
				2	16.5
				3	27.5
				4	38.5
				5	49.5
				6	64.9
				7	75.9
D055	Main Building of the University of Hong Kong	0, 34.6 and 84.7	6/2/06 & 14/02/06	1	5
				2	10
				3	15
				4	25
				5	35
				6	45
				7	60
D064	Hill Road	0, 54.6 and 66.7	1/12/05 & 3/12/05	1	6.5
				2	16.5
				3	27.5
				4	38.5
				5	55
				6	66
				7	77
D078	Starr Hall of the University of Hong Kong	0, 49.2 and 93.3	12/01/06 & 17/01/06	1	5
				2	16
				3	25
				4	35
				5	45
				6	55
				7	65
D086	University Heights	0, 49.5 and 67.5	13/01/06 & 16/01/06	1	6.5
				2	16.5
				3	27.5
				4	38.5
				5	47.3
				6	57.2
				7	71.5
D095	Forbes Street Temporary Playground	0, 10.4 and 21.1	19/10/05, 20/10/05 & 21/10/05	1	5
				2	15
				3	26
				4	37
				5	47
				6	57
				7	70
D0103	Forbes Street Sai Wan Estate	12.9 and 21	13/12/05 & 15/12/05	1	7.1
				2	12.1
				3	20.6
				4	30.4
				5	50.2
				6	60.2
				7	75.2

Photos

PHOTO 1 IMPACT HAMMER AND DOWNHOLE LOAD CELL ATTACHED, RESPECTIVELY, TO THE TOP AND BOTTOM OF THE DRILL STRING AT IMPACT BOREHOLE 024 INSIDE TSAN YUK HOSPITAL

PHOTO 2 GEOPHONE MOUNTED ON THE FLOOR OF THE TSAN YUK HOSPITAL

PHOTO 3 ACCELEROMETRE MOUNTED ON THE FLOOR OF THE TSAN YUK HOSPITAL



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WEST ISLAND LINE ENVIRONMENTAL IMPACT ASSESSMENT

WEST ISLAND LINE BOREHOLE LOCATIONS KEY PLAN

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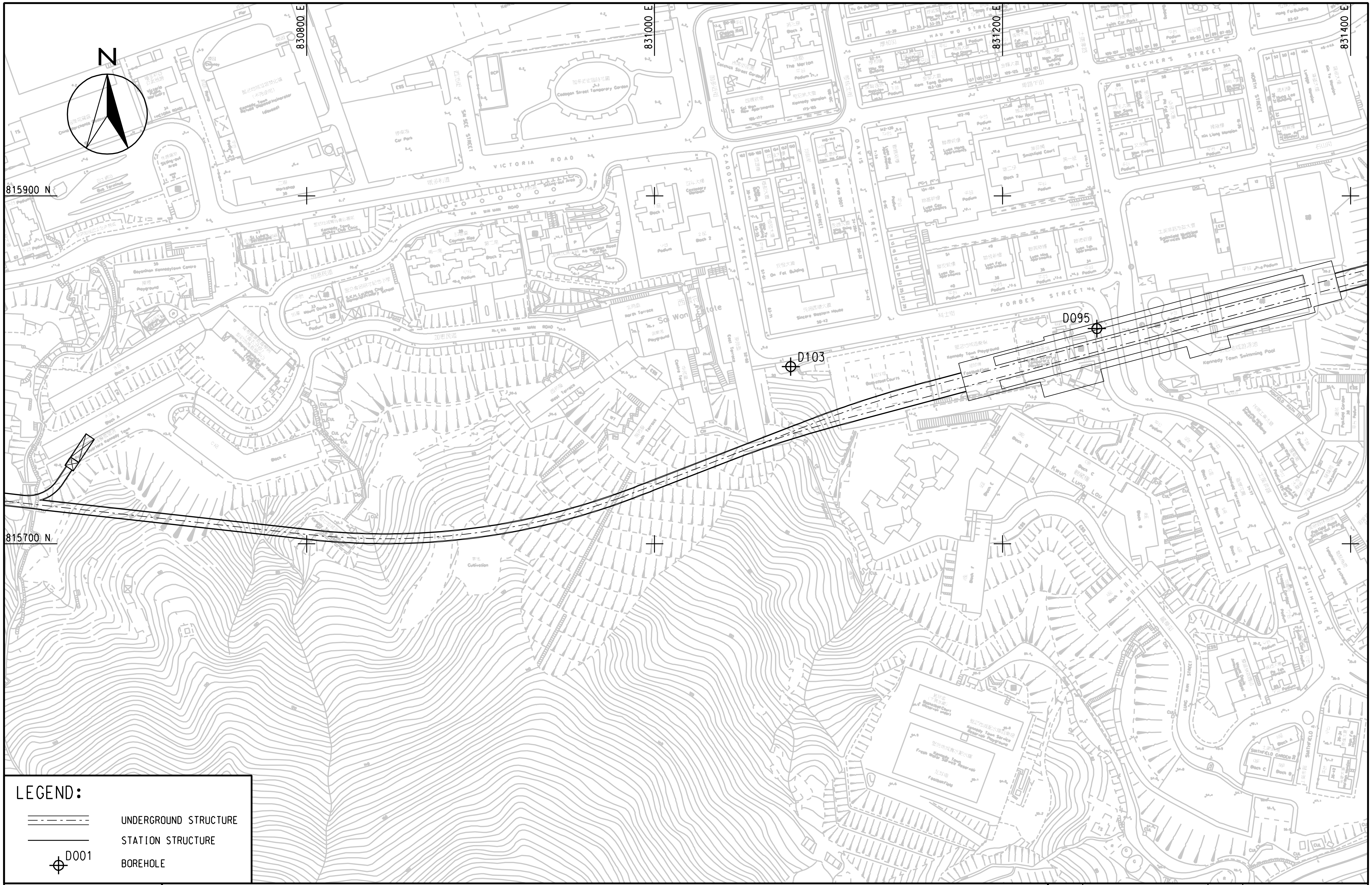

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WEST ISLAND LINE ENVIRONMENTAL IMPACT ASSESSMENT

WEST ISLAND LINE BOREHOLE LOCATIONS

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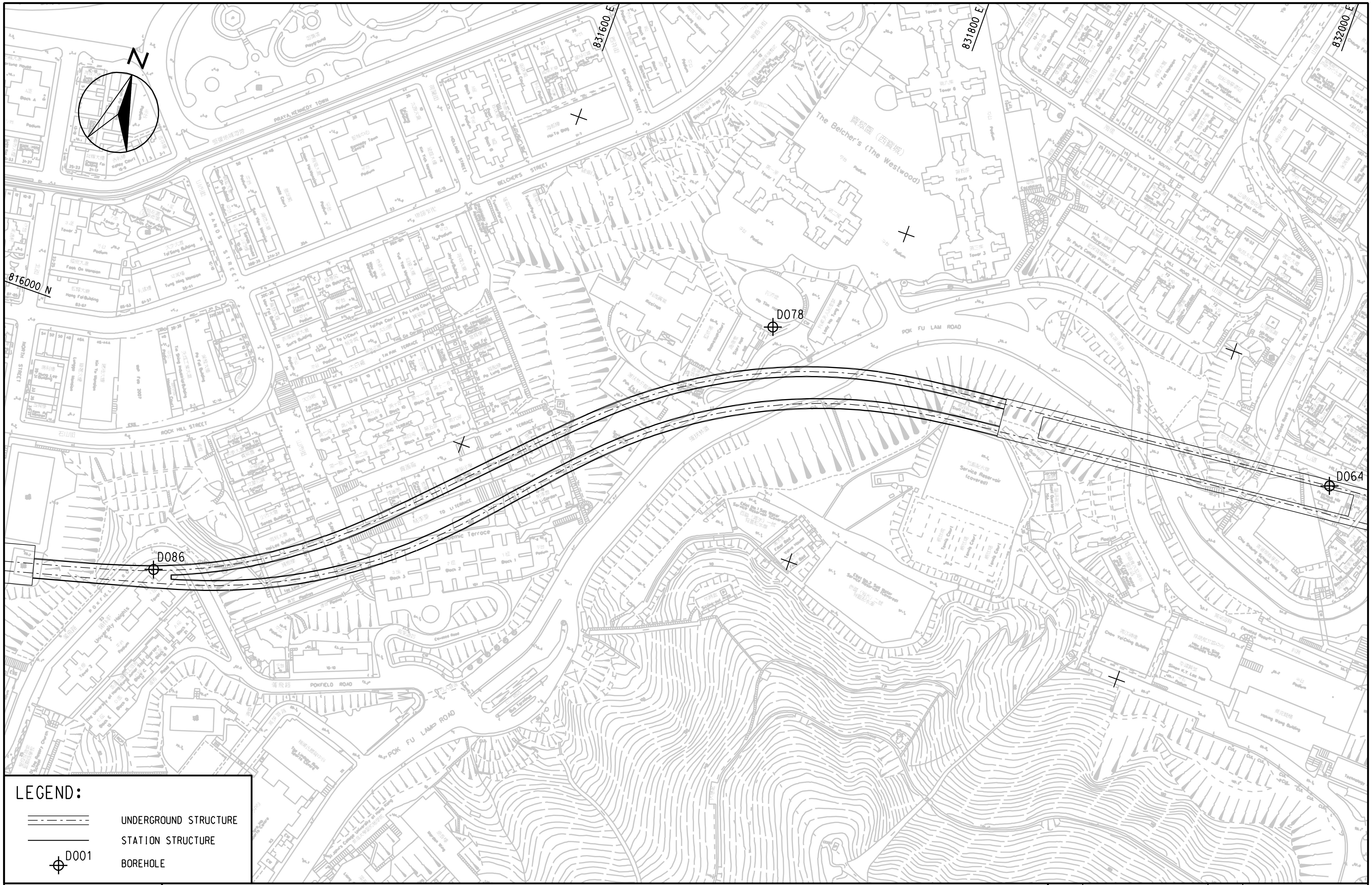

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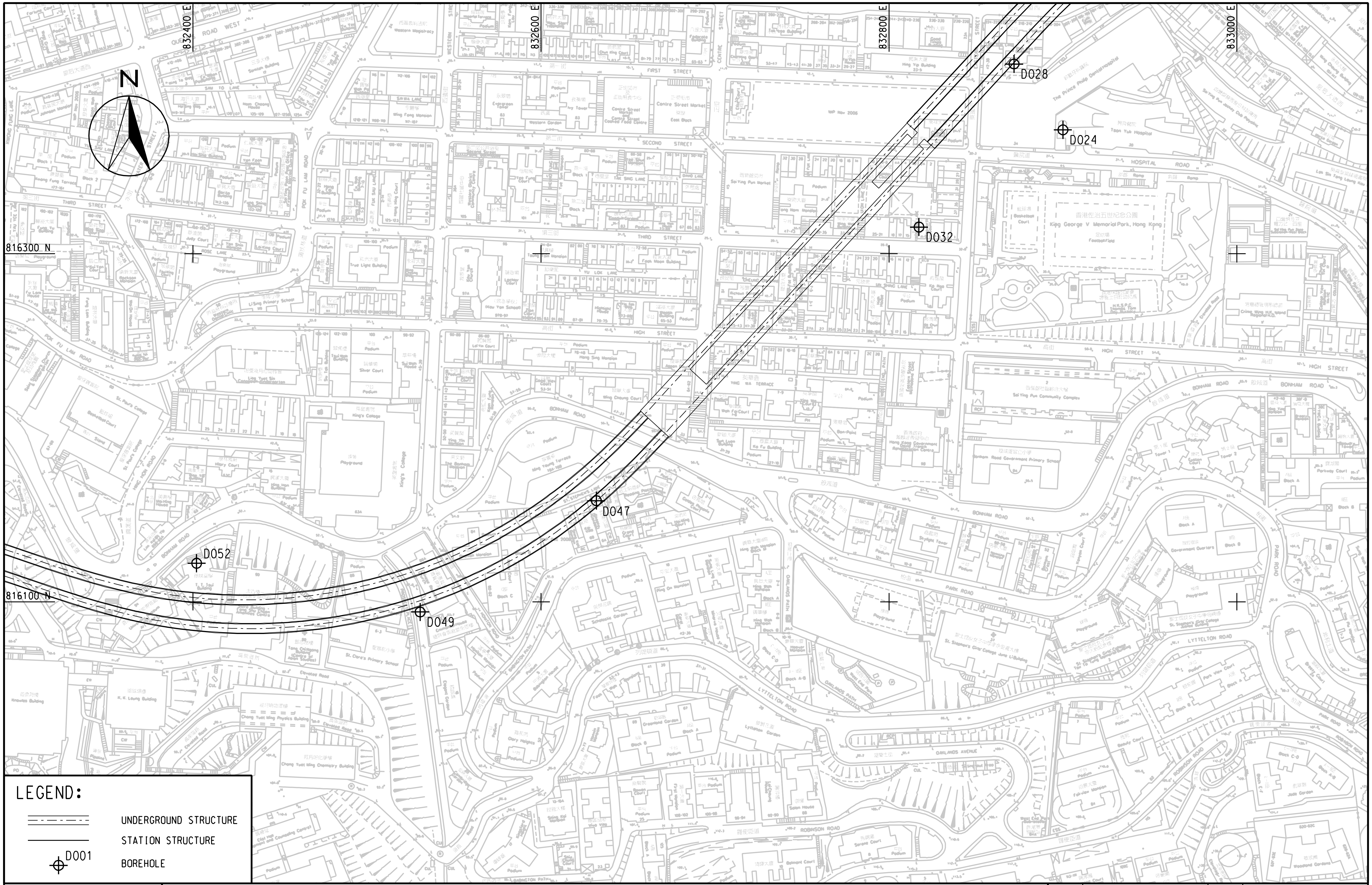

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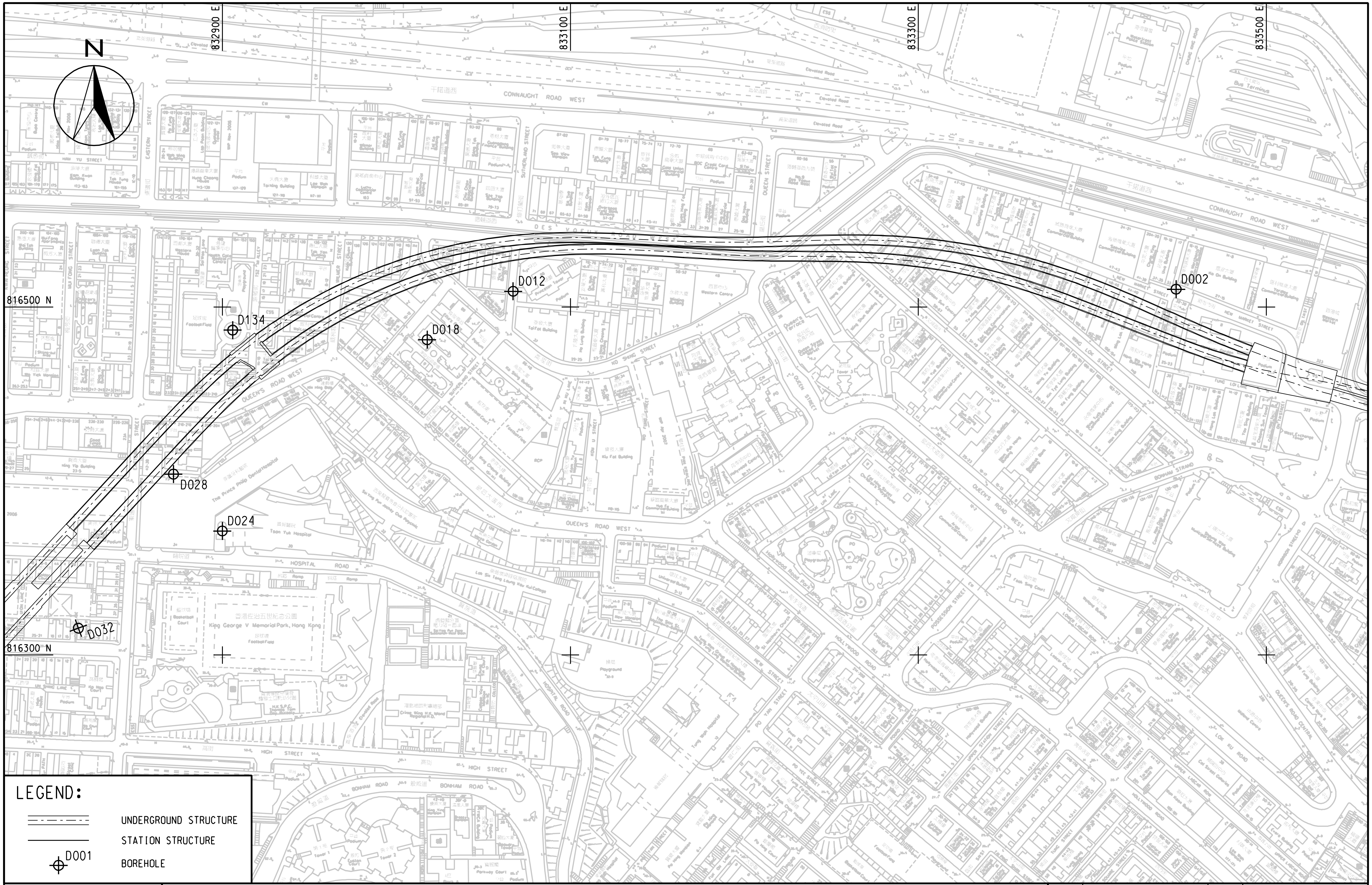

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MAUSELL
ENSR Asia (HK) Ltd.

WEST ISLAND LINE ENVIRONMENTAL IMPACT ASSESSMENT

WEST ISLAND LINE BOREHOLE LOCATIONS

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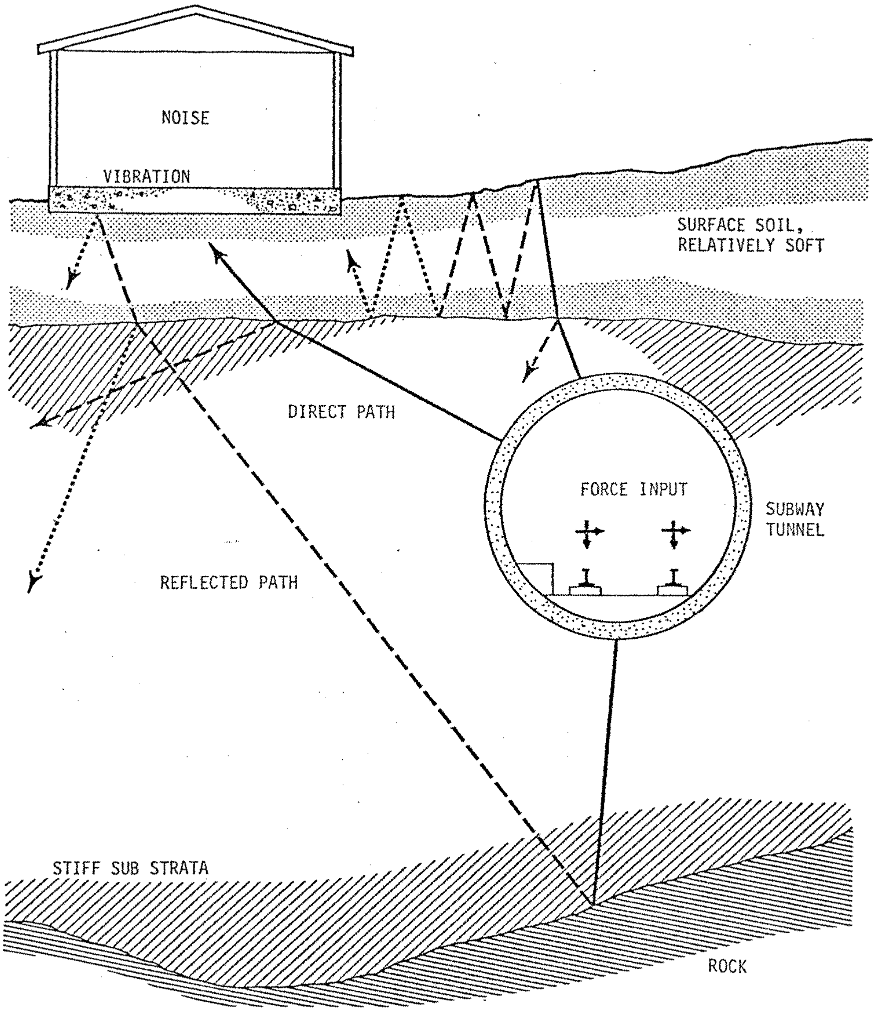

FIGURE 2 SCHEMATIC OF VIBRATION PROPAGATION PATHS FROM TRANSIT TUNNEL TO RECEIVER BUILDING

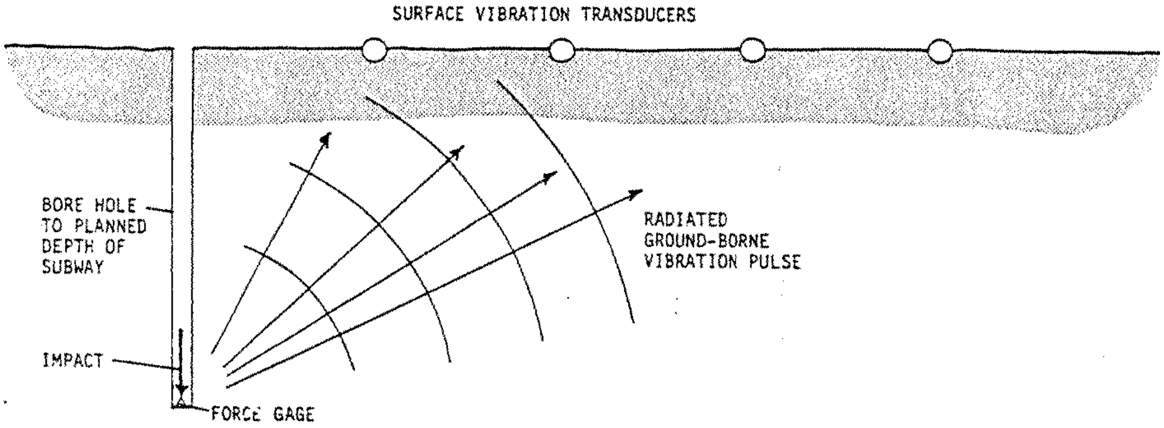

FIGURE 3 SCHEMATIC OF BOREHOLE TEST WHERE IMPACTING OCCURS AT THE END OF THE DRILL STRING AND VIBRATION RECEIVERS ARE PLACED ON THE SURFACE

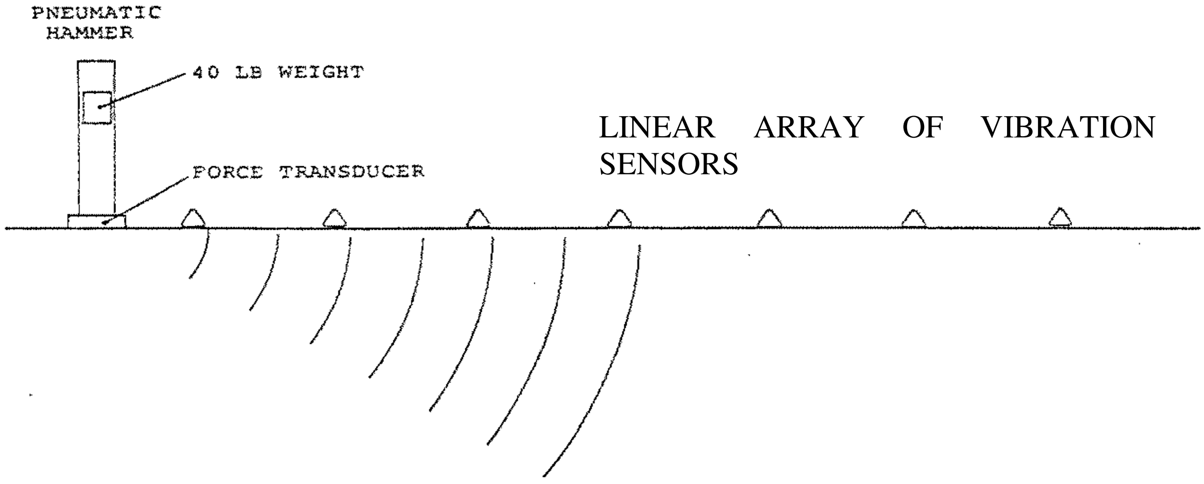

FIGURE 4 SCHEMATIC OF MEASUREMENT SCHEME FOR IMPACTING WITH AN INSTRUMENTED HAMMER FOR DETERMINATION OF THE PSR

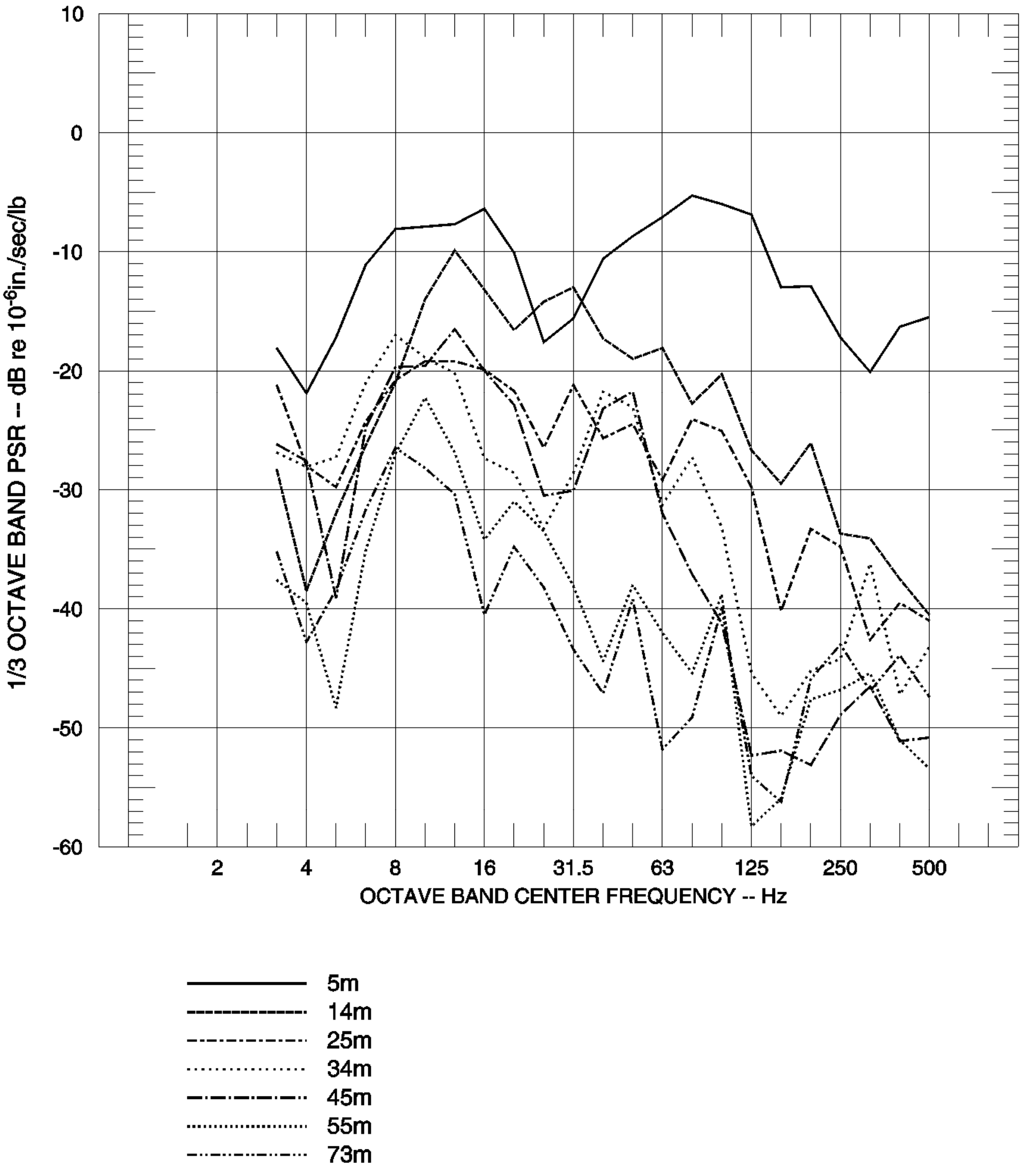

FIGURE 5 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D002 WITH THE DEPTH OF 19.6m

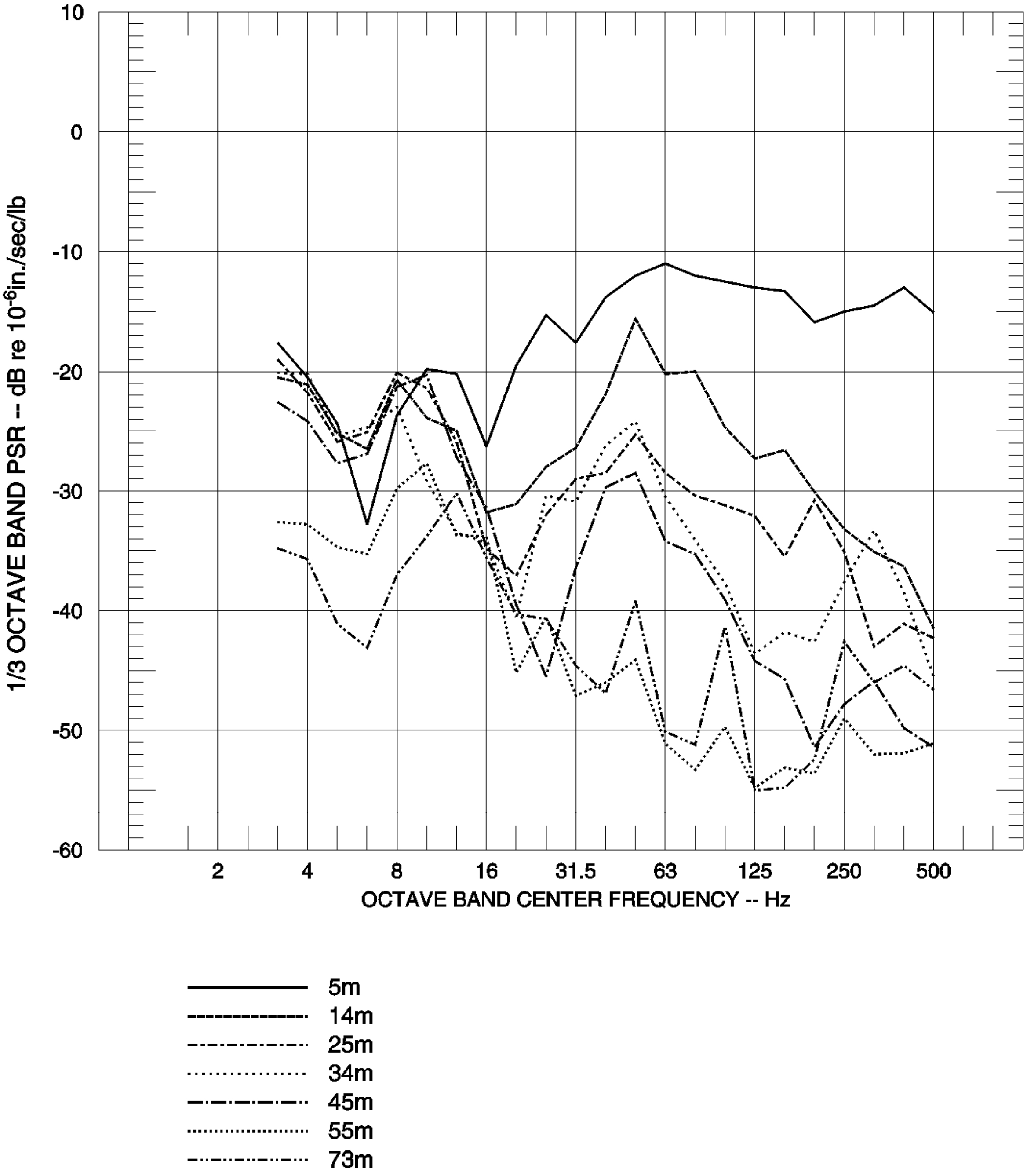

FIGURE 6 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D002 WITH THE DEPTH OF 33.7m

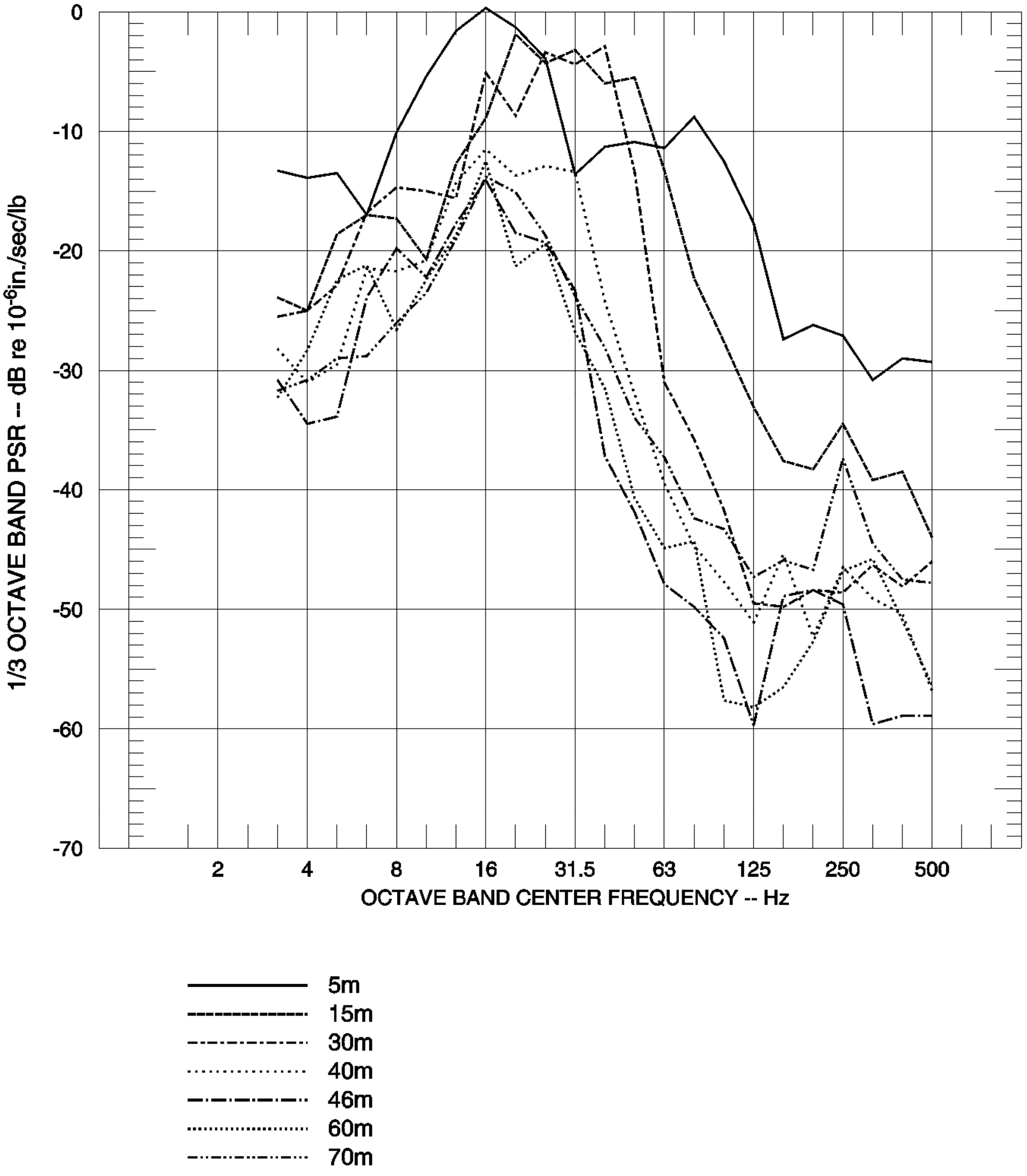

FIGURE 7 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D012 WITH THE DEPTH OF 18m

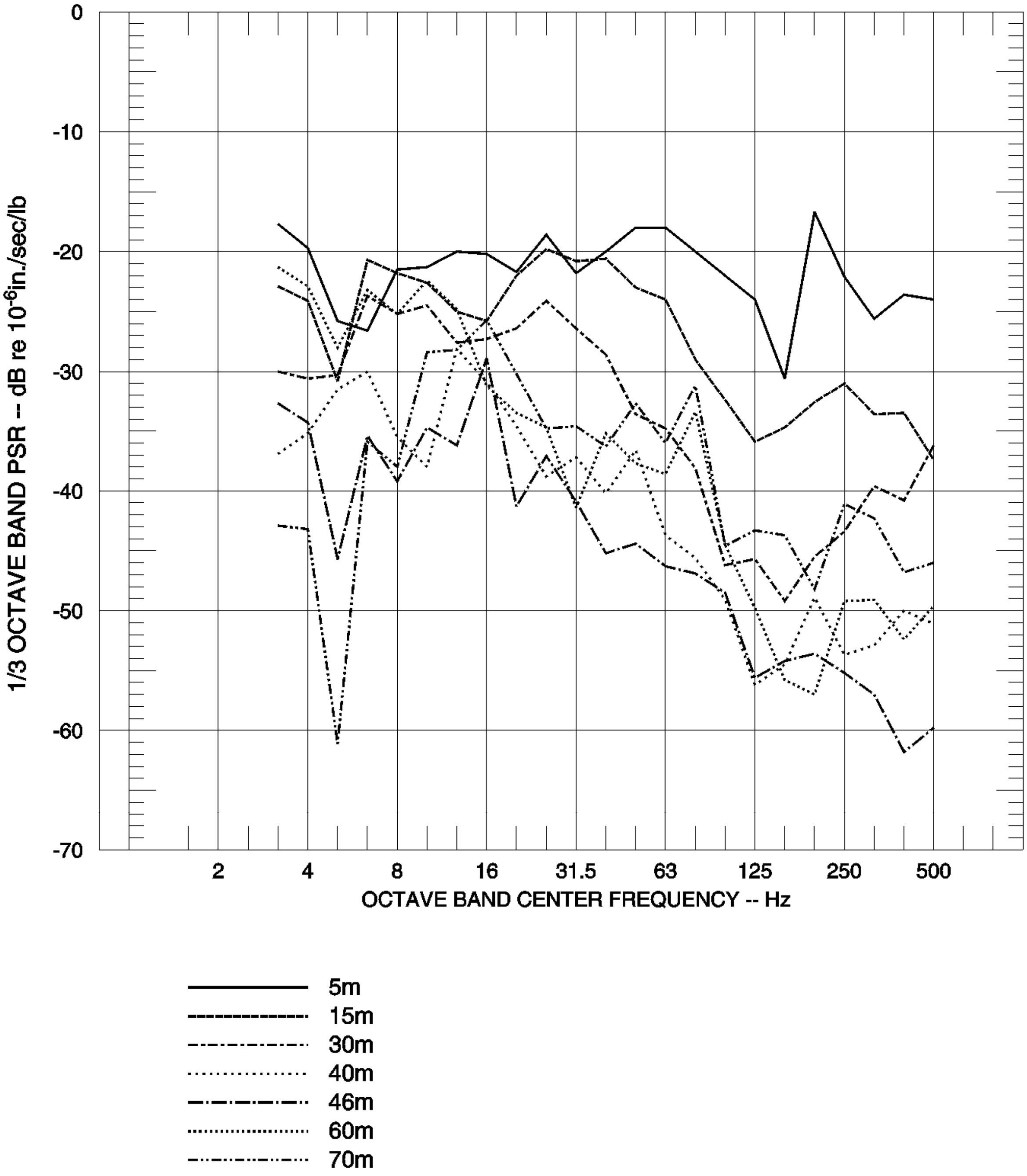

FIGURE 8 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D012 WITH THE DEPTH OF 41.4m

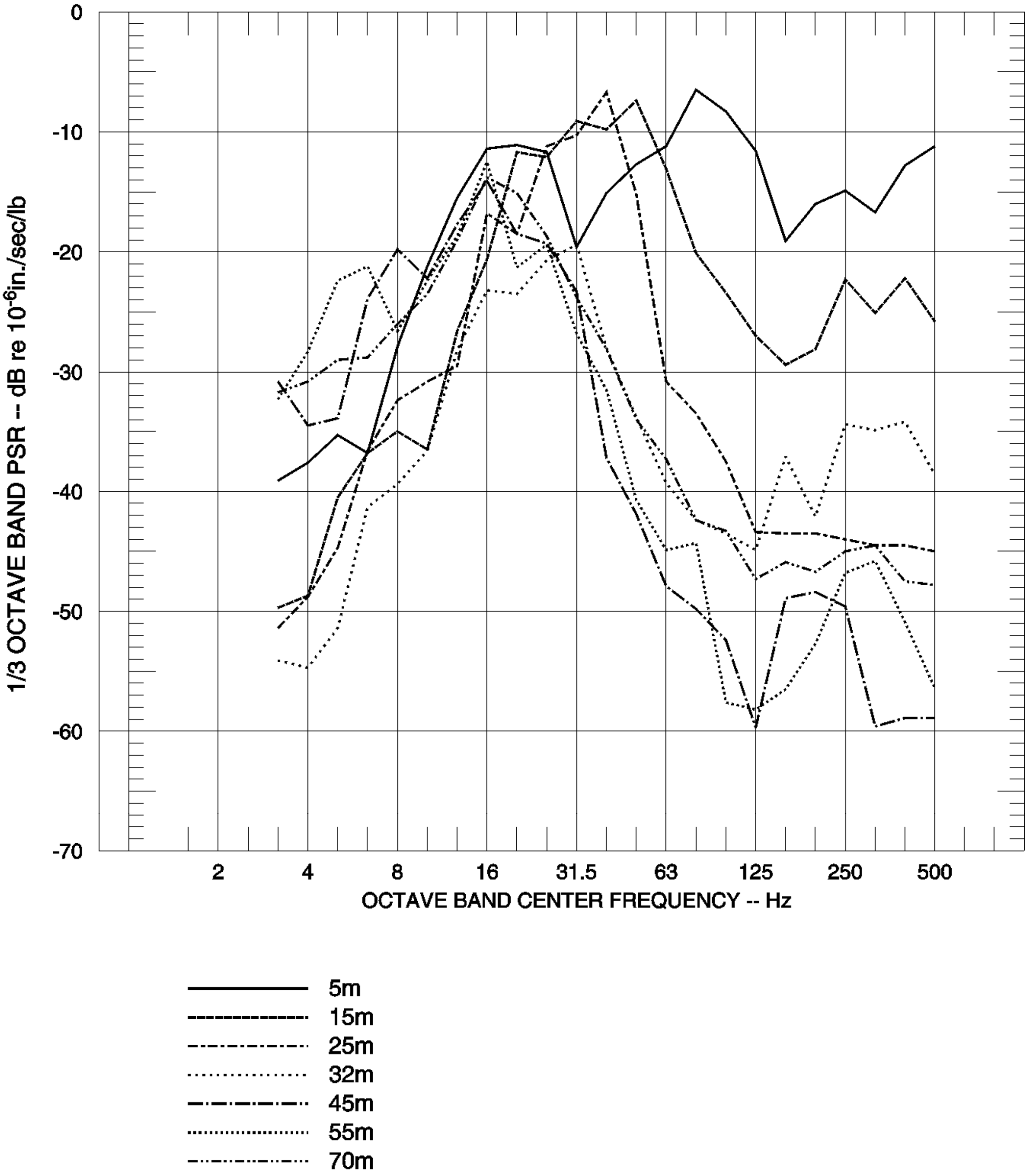

FIGURE 9 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D018 WITH THE DEPTH OF 14.9m

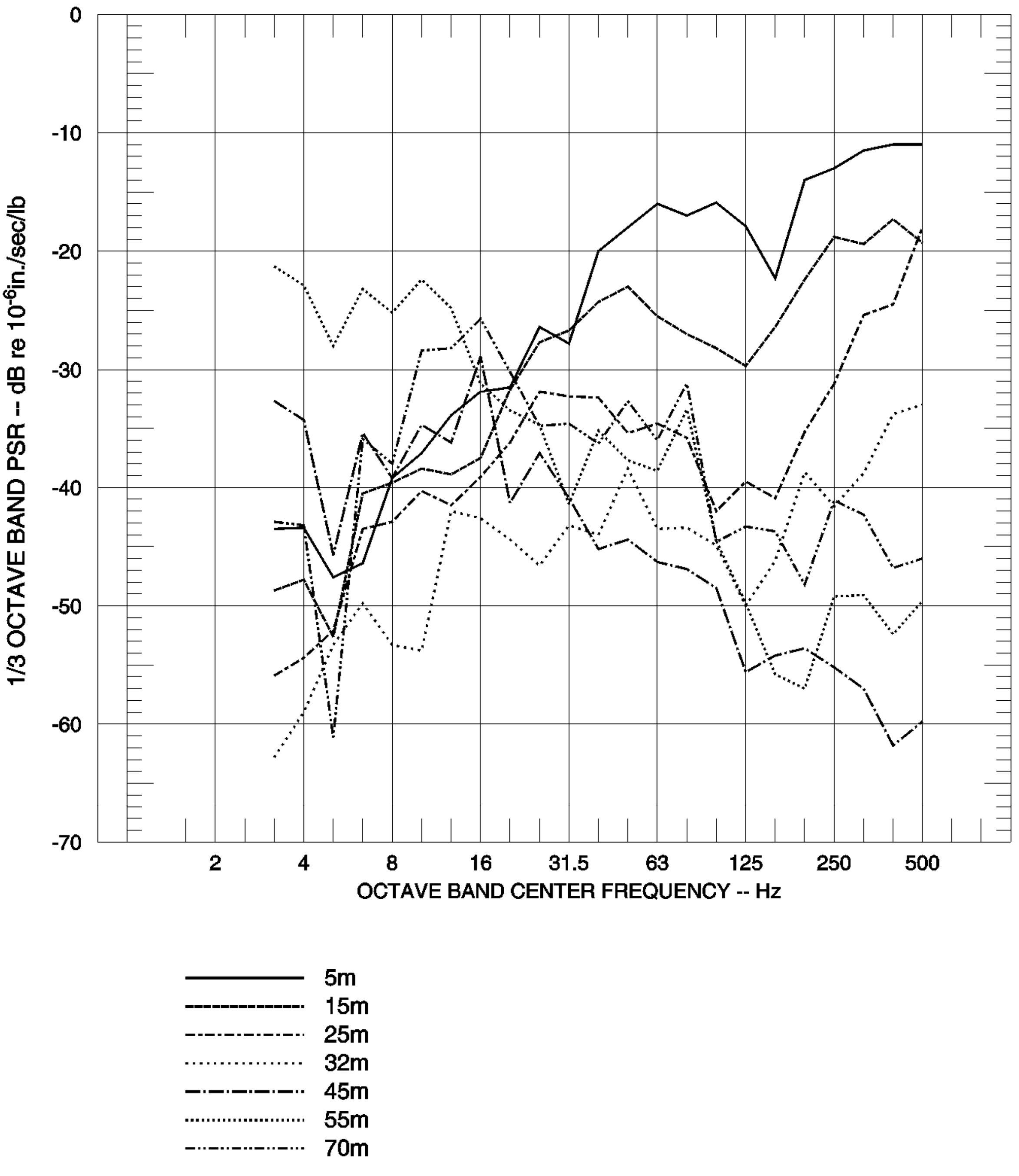

FIGURE 10 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D018 WITH THE DEPTH OF 39.8m

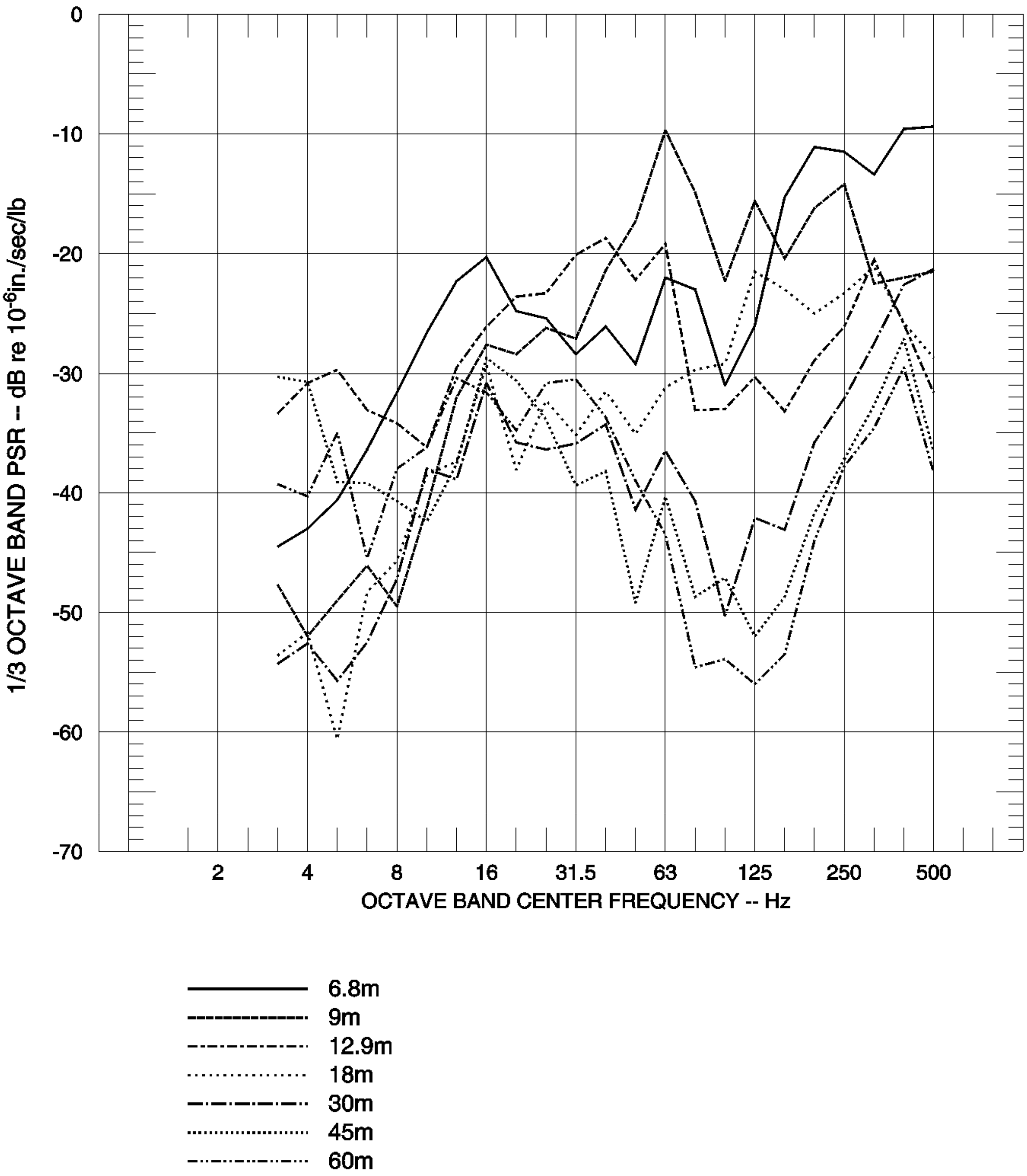

FIGURE 11 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D028 WITH THE DEPTH OF 44.3m

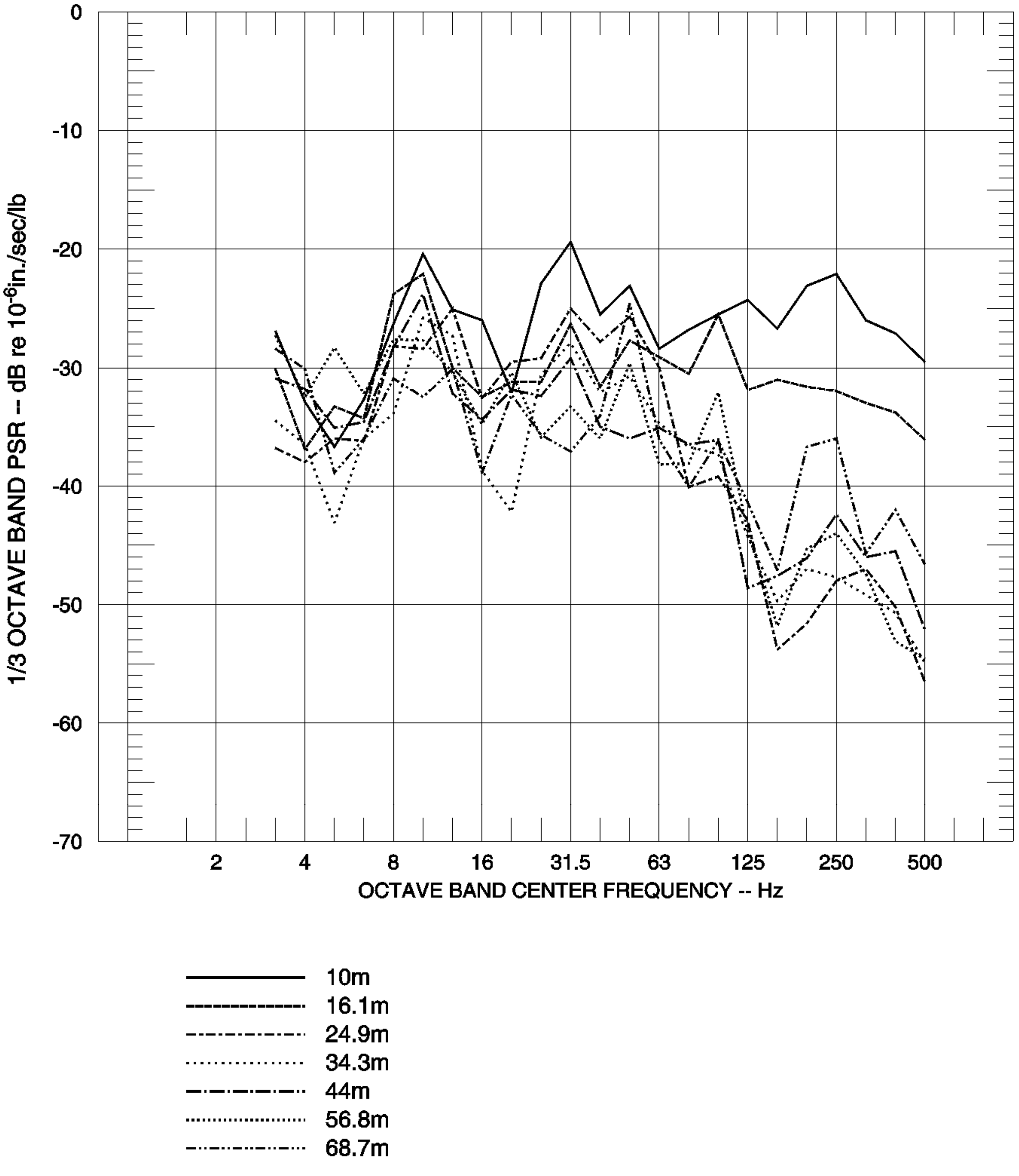

FIGURE 12 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D032 WITH THE DEPTH OF 57.3m

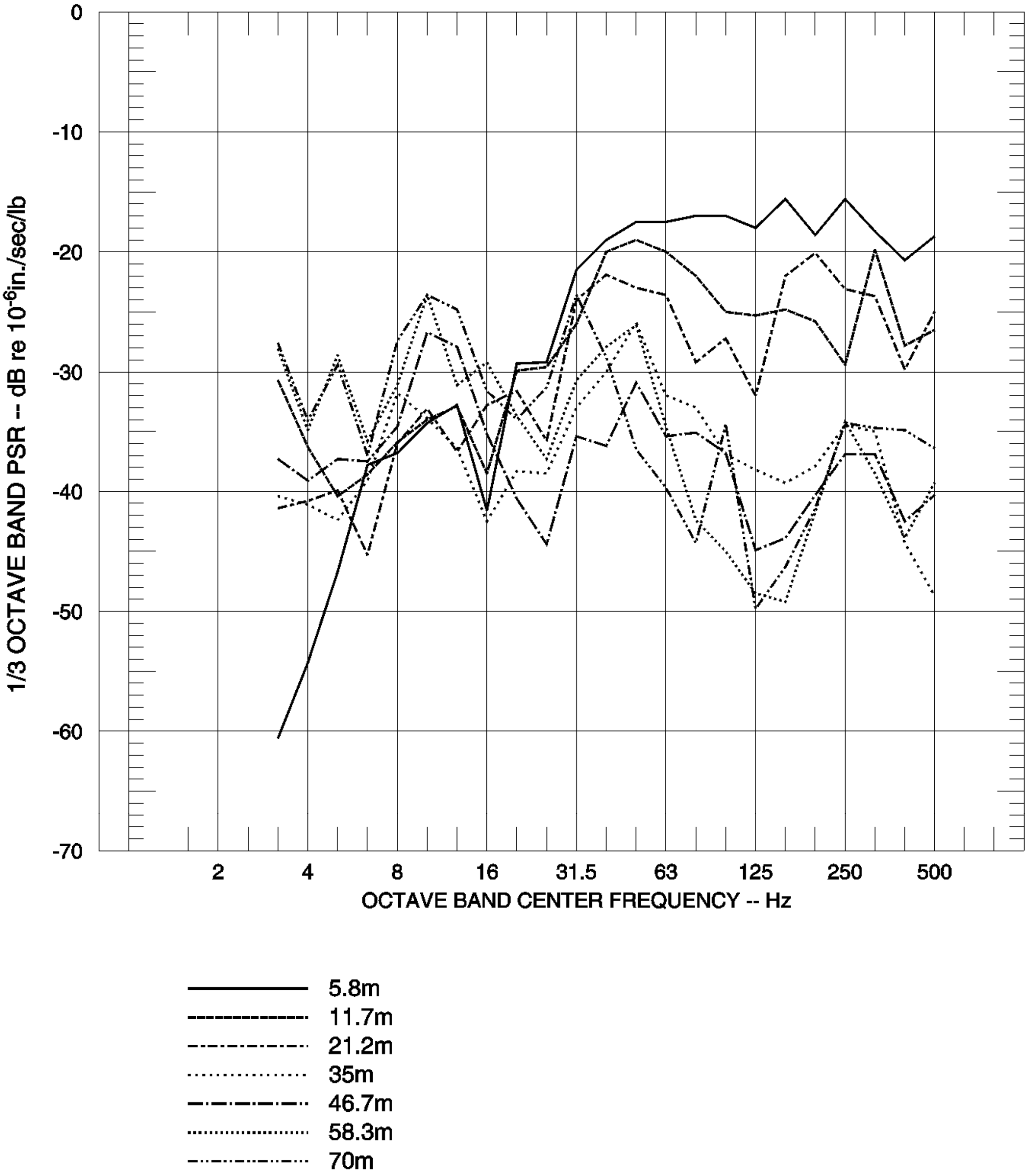

FIGURE 13 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D047 WITH THE DEPTH OF 95.6m

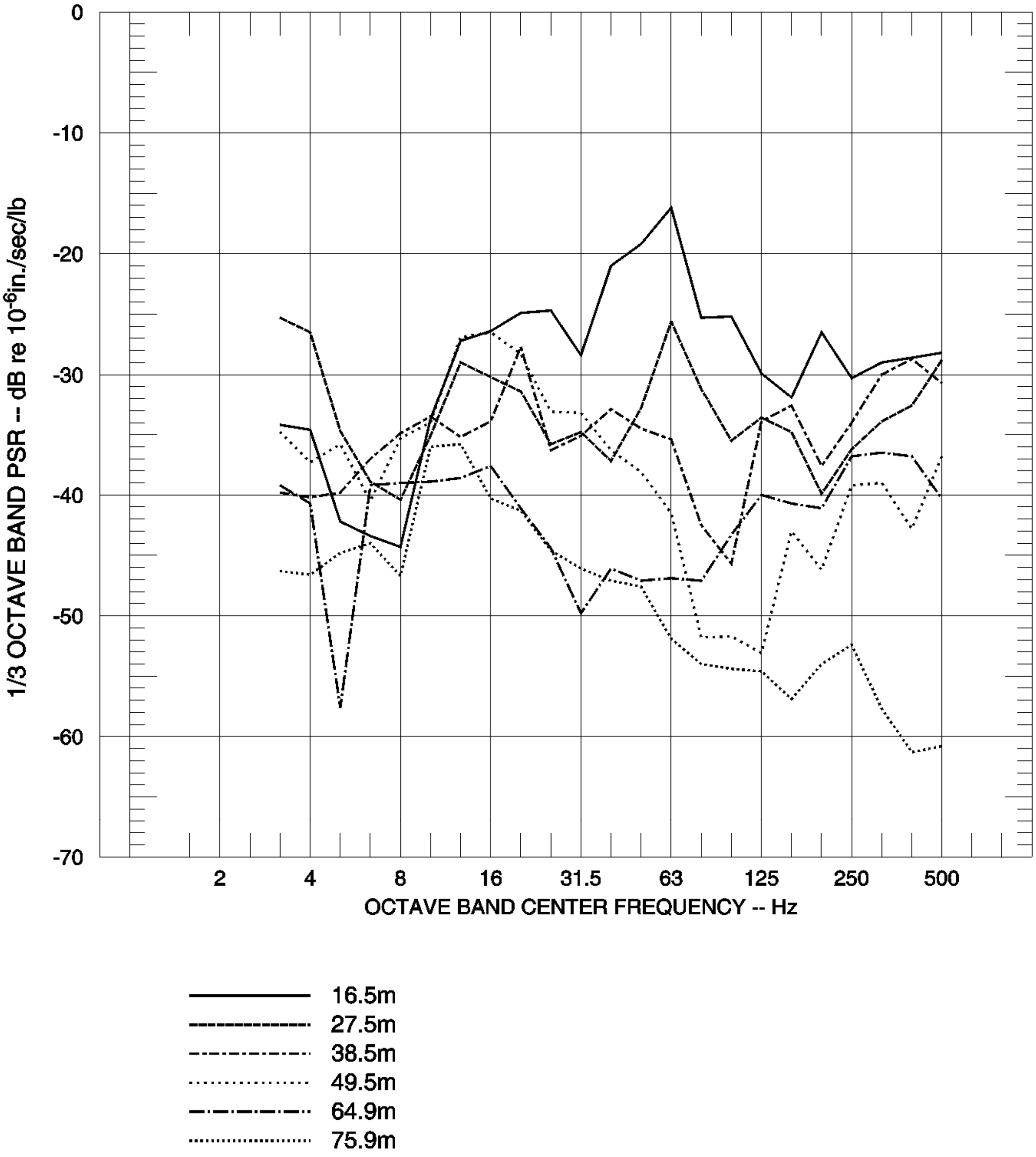

FIGURE 14 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D049 WITH THE DEPTH OF 60.4m

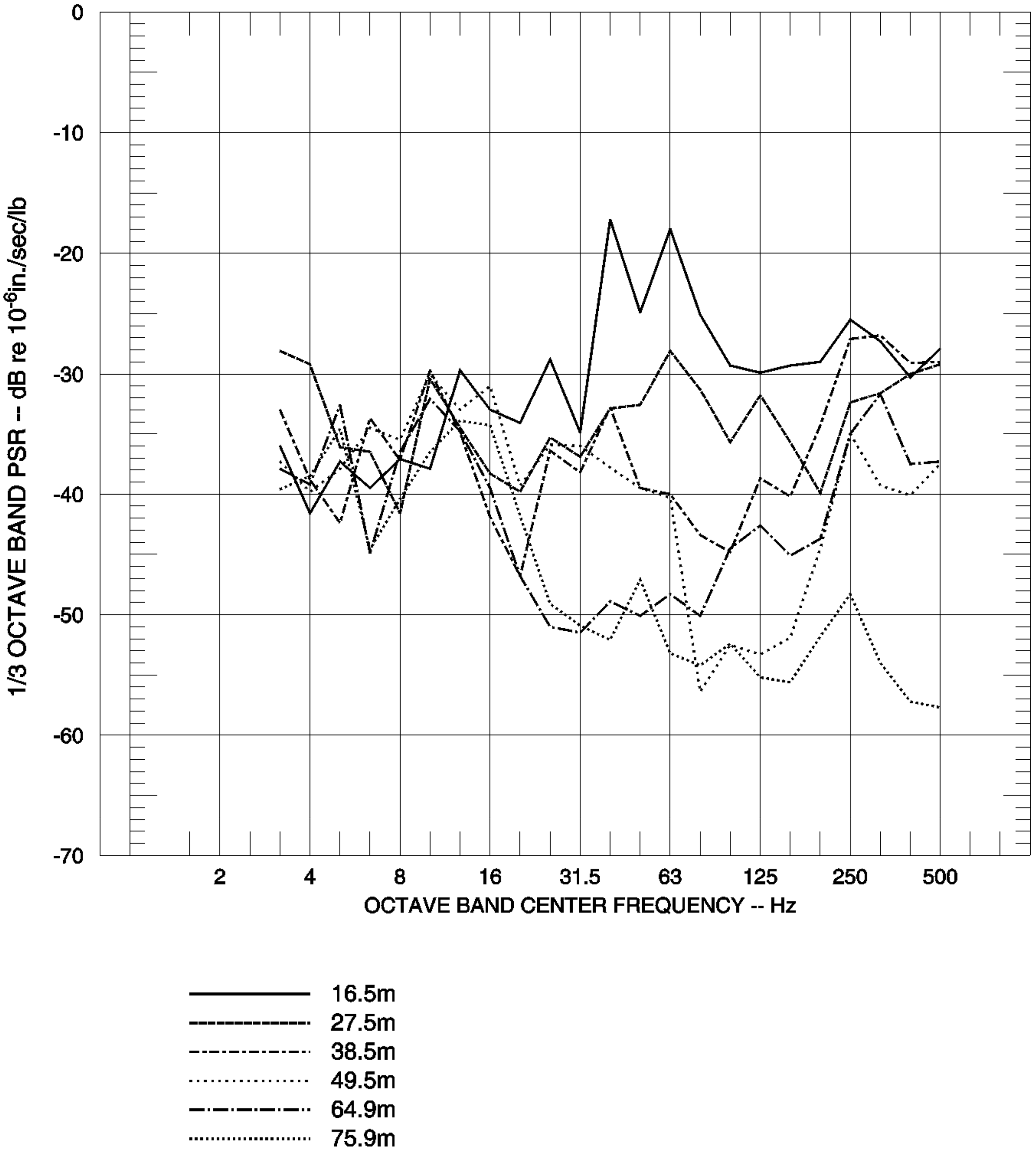

FIGURE 15 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D049 WITH THE DEPTH OF 87.8m

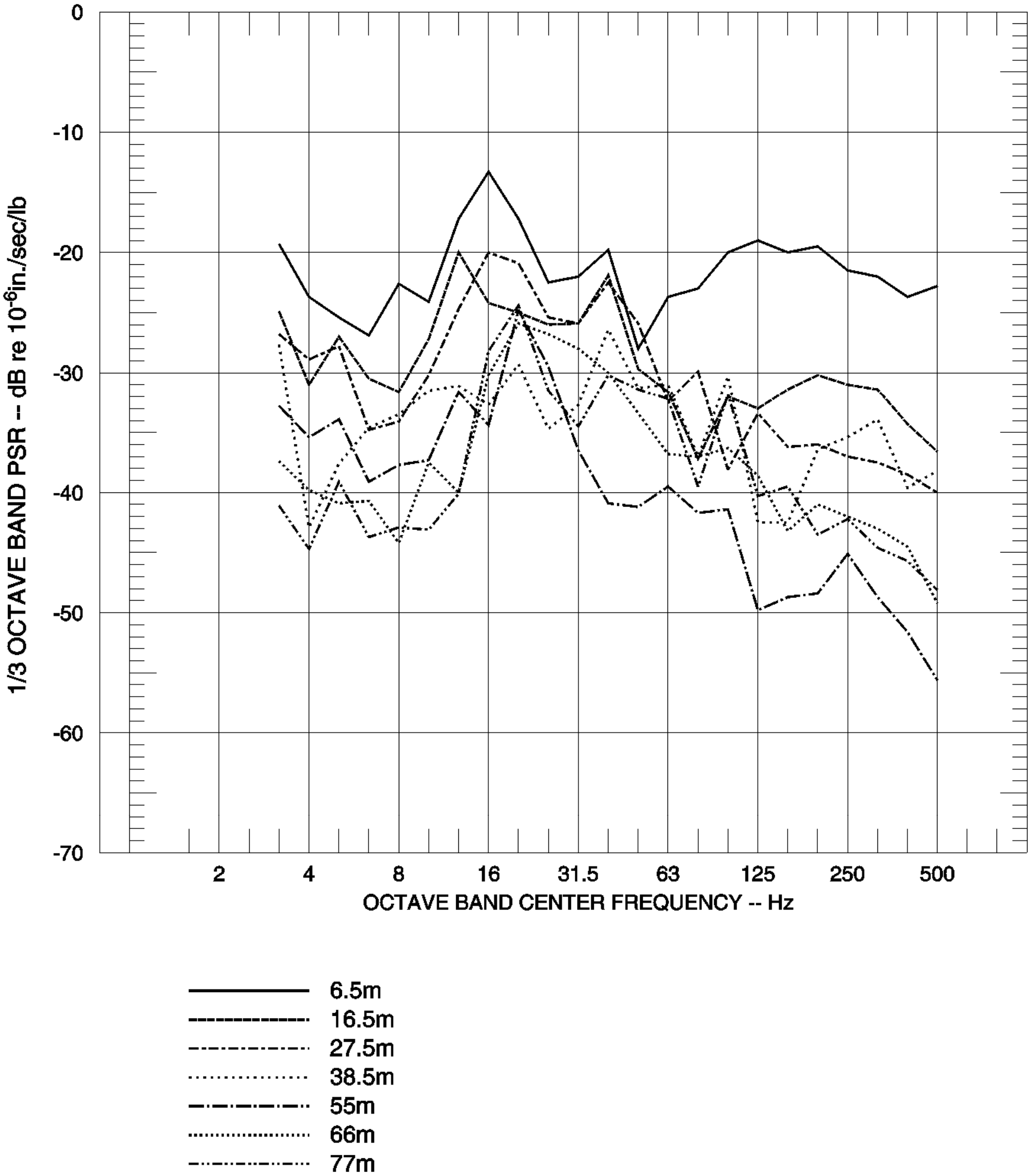

FIGURE 16 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D064 WITH THE DEPTH OF 54.6m

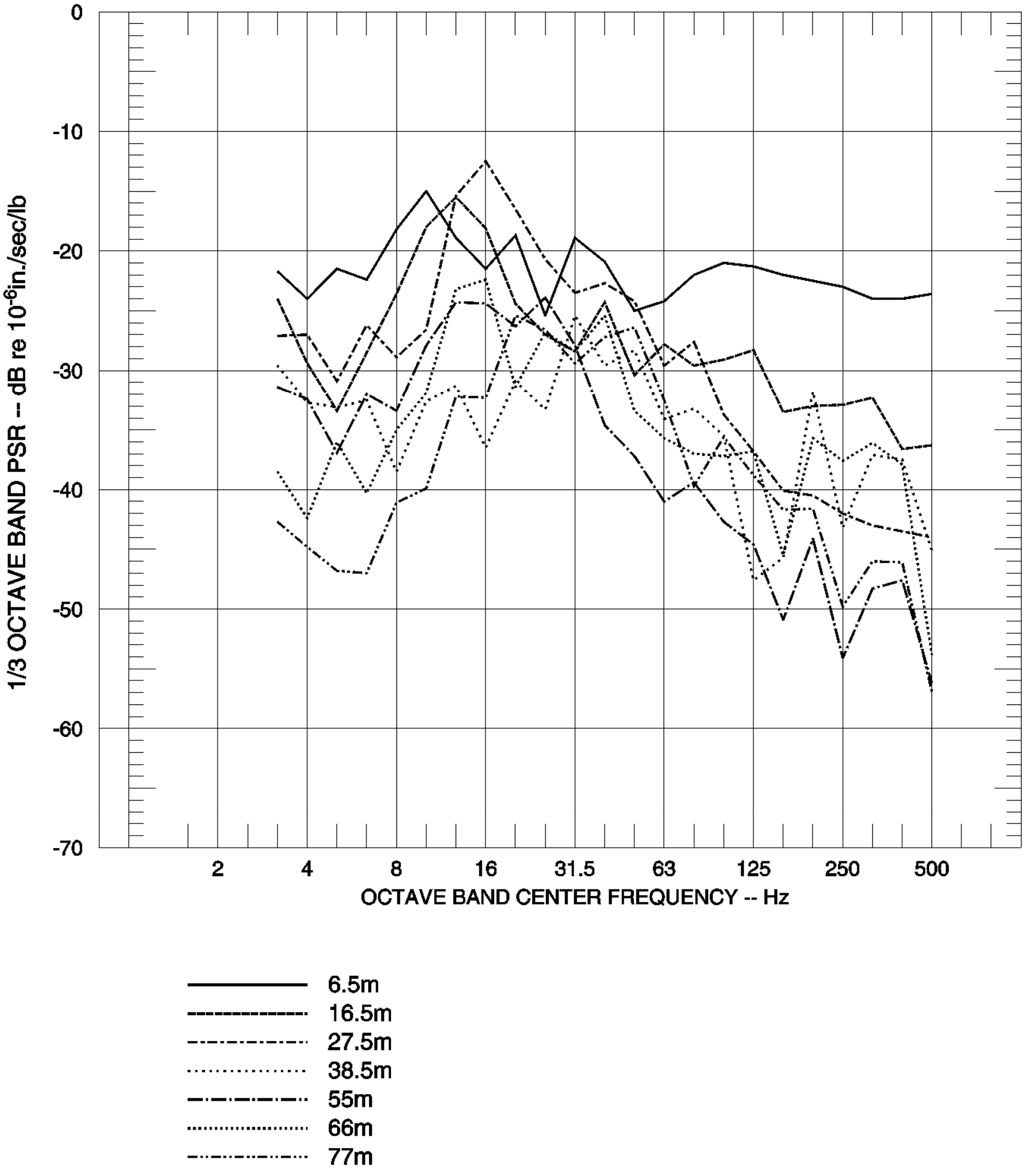

FIGURE 17 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D064 WITH THE DEPTH OF 66.7m

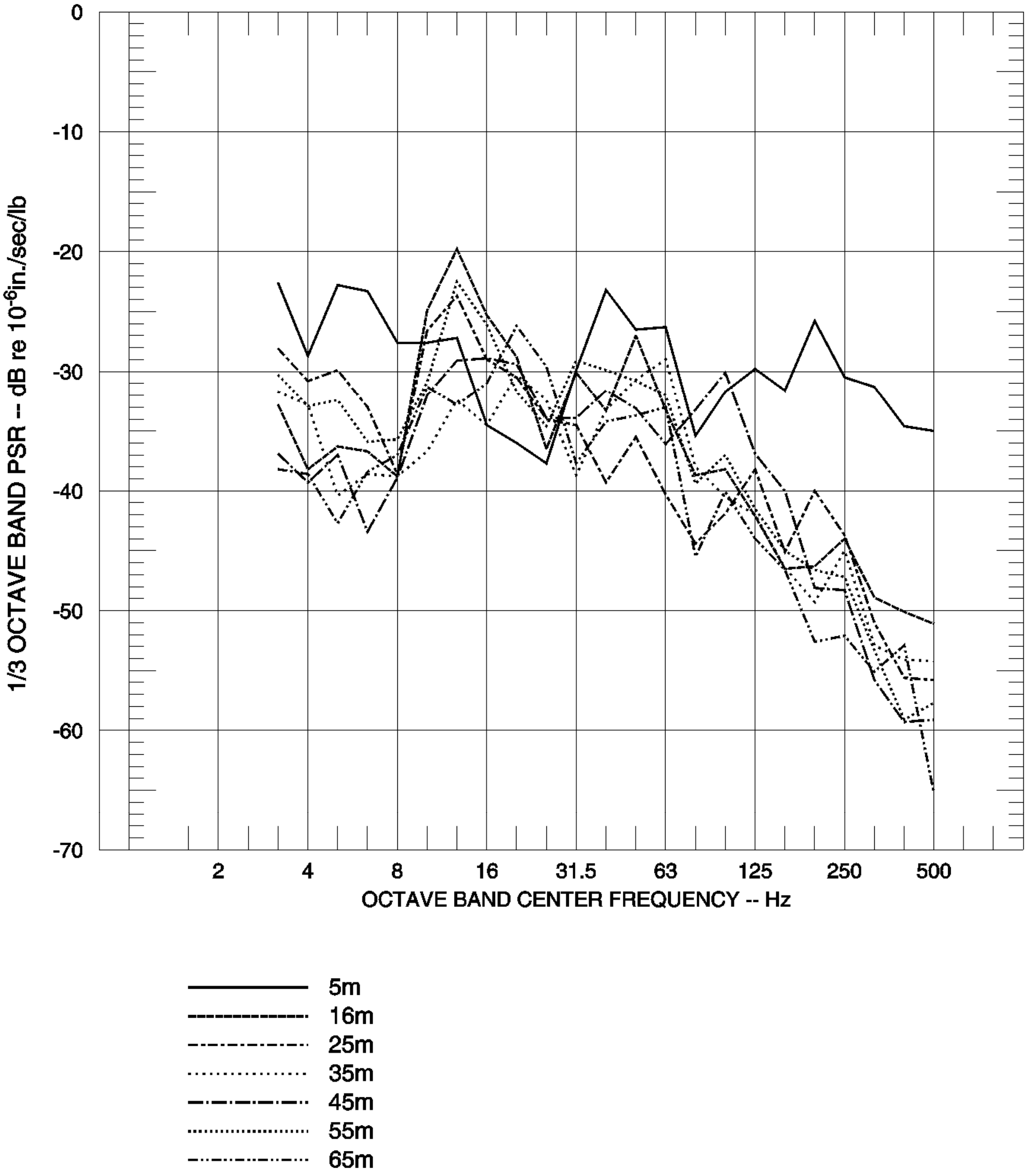

FIGURE 18 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D078 WITH THE DEPTH OF 49.2m

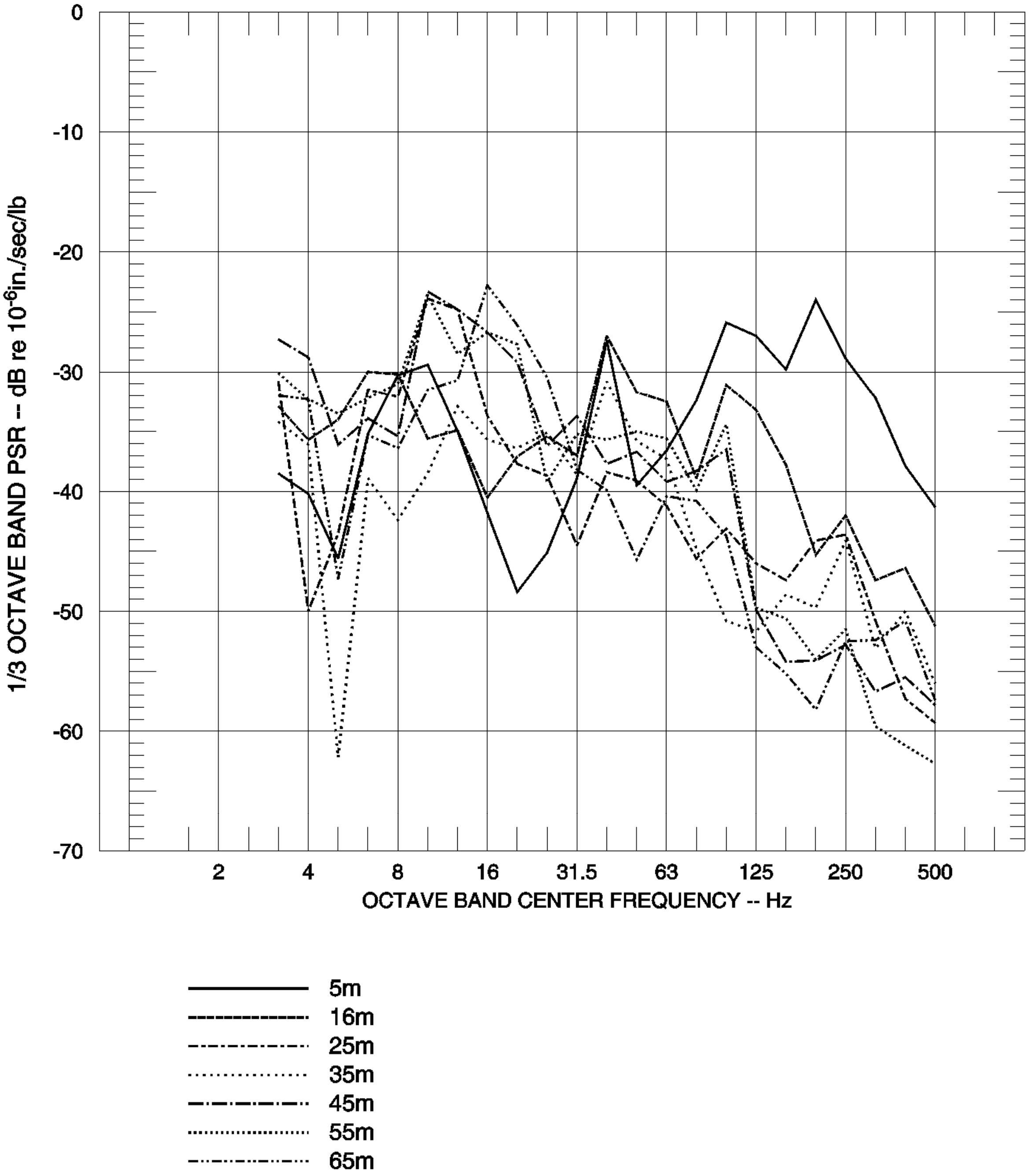

FIGURE 19 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D078 WITH THE DEPTH OF 93.3m

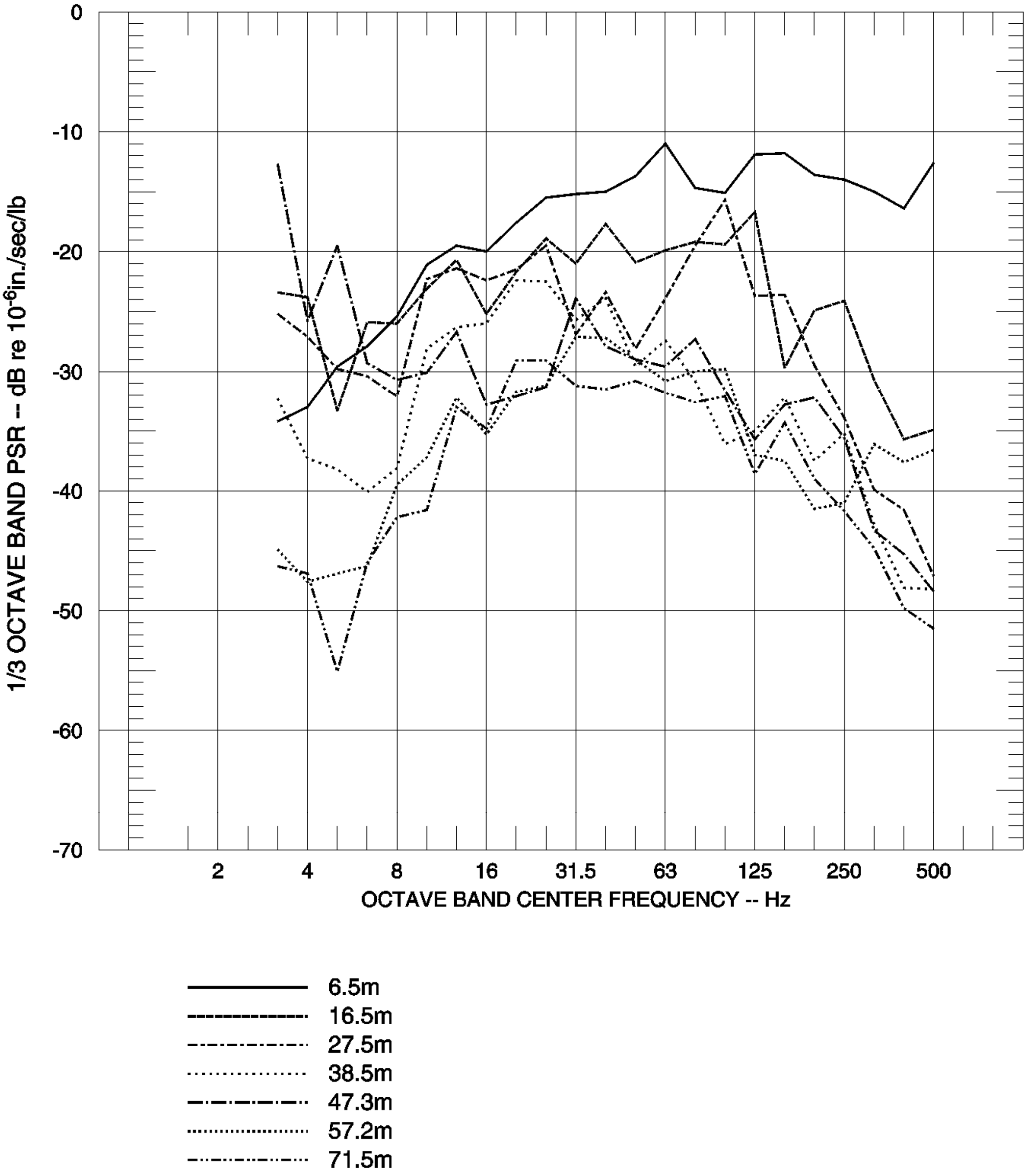

FIGURE 20 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D086 WITH THE DEPTH OF 49.5m

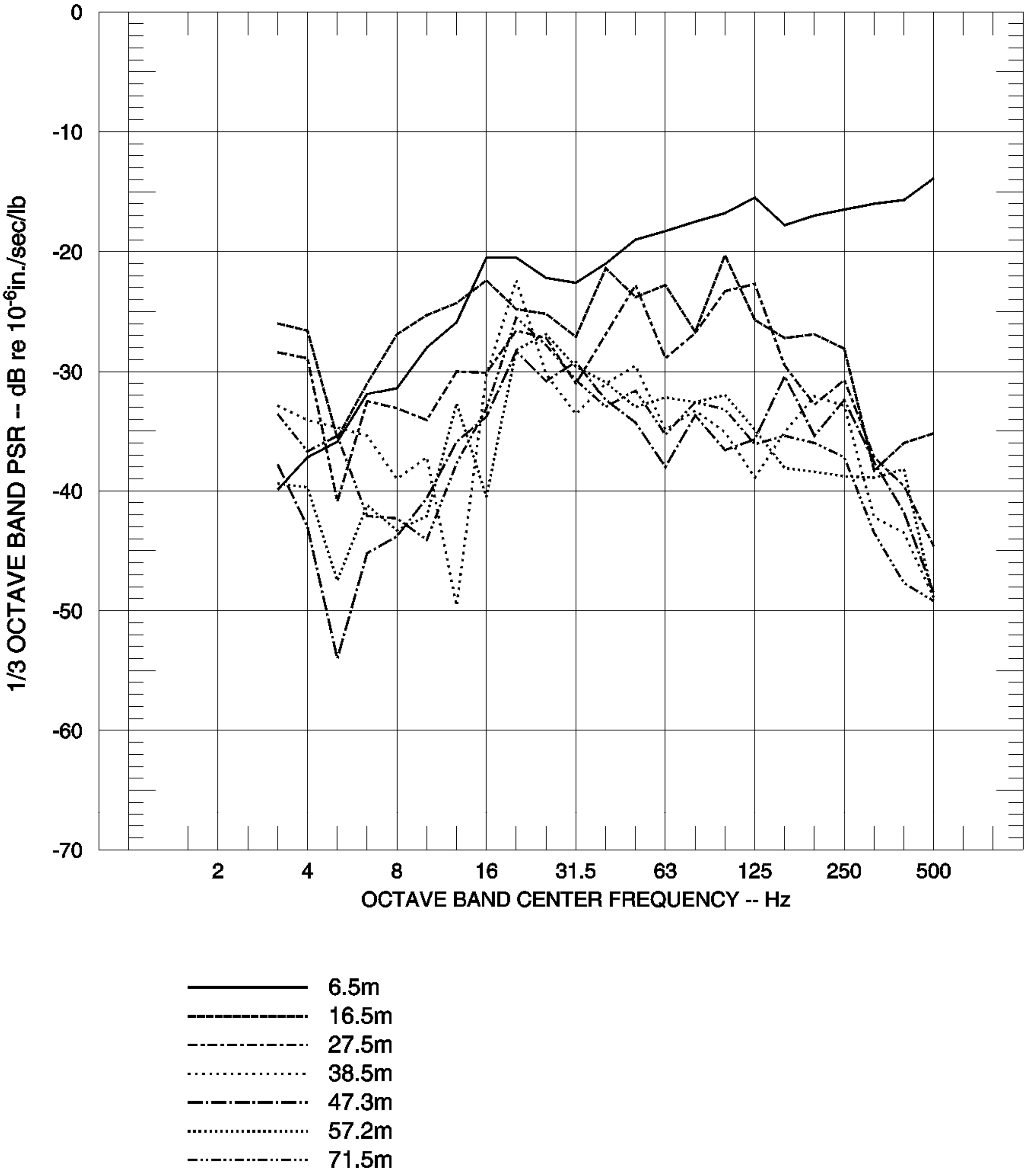

FIGURE 21 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D086 WITH THE DEPTH OF 67.5m

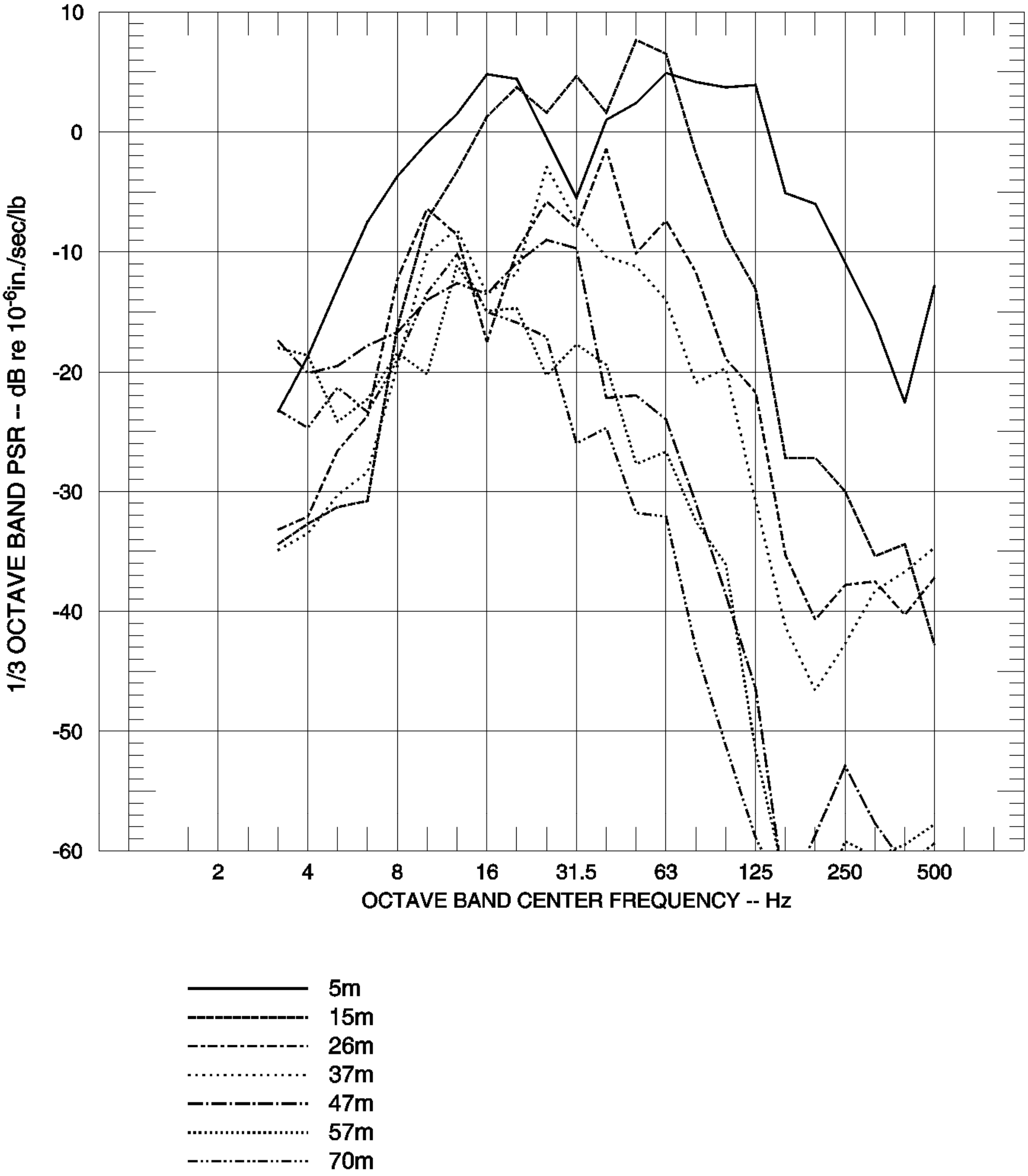

FIGURE 22 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D095 WITH THE DEPTH OF 10.4m

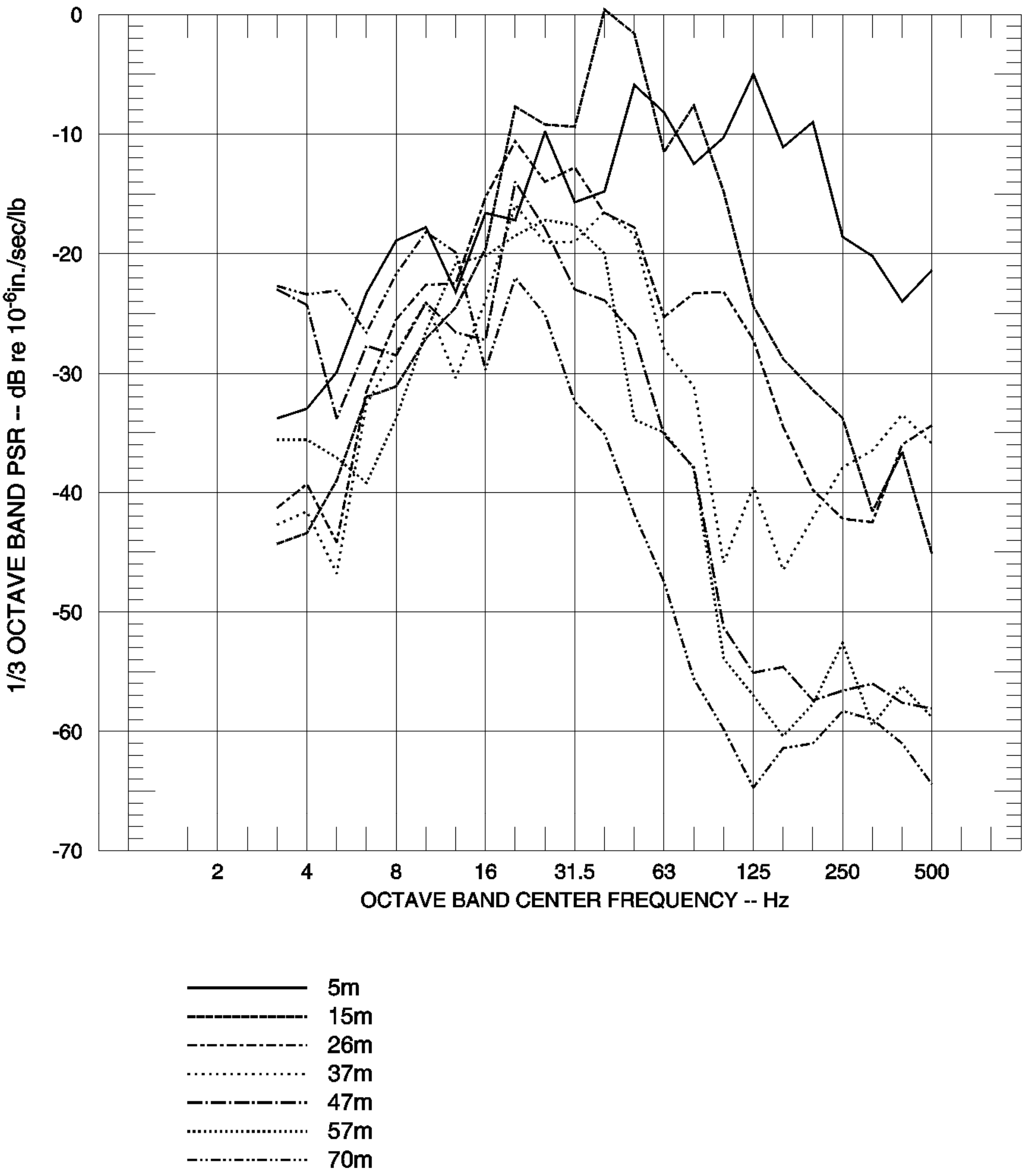

FIGURE 23 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D095 WITH THE DEPTH OF 21.1m

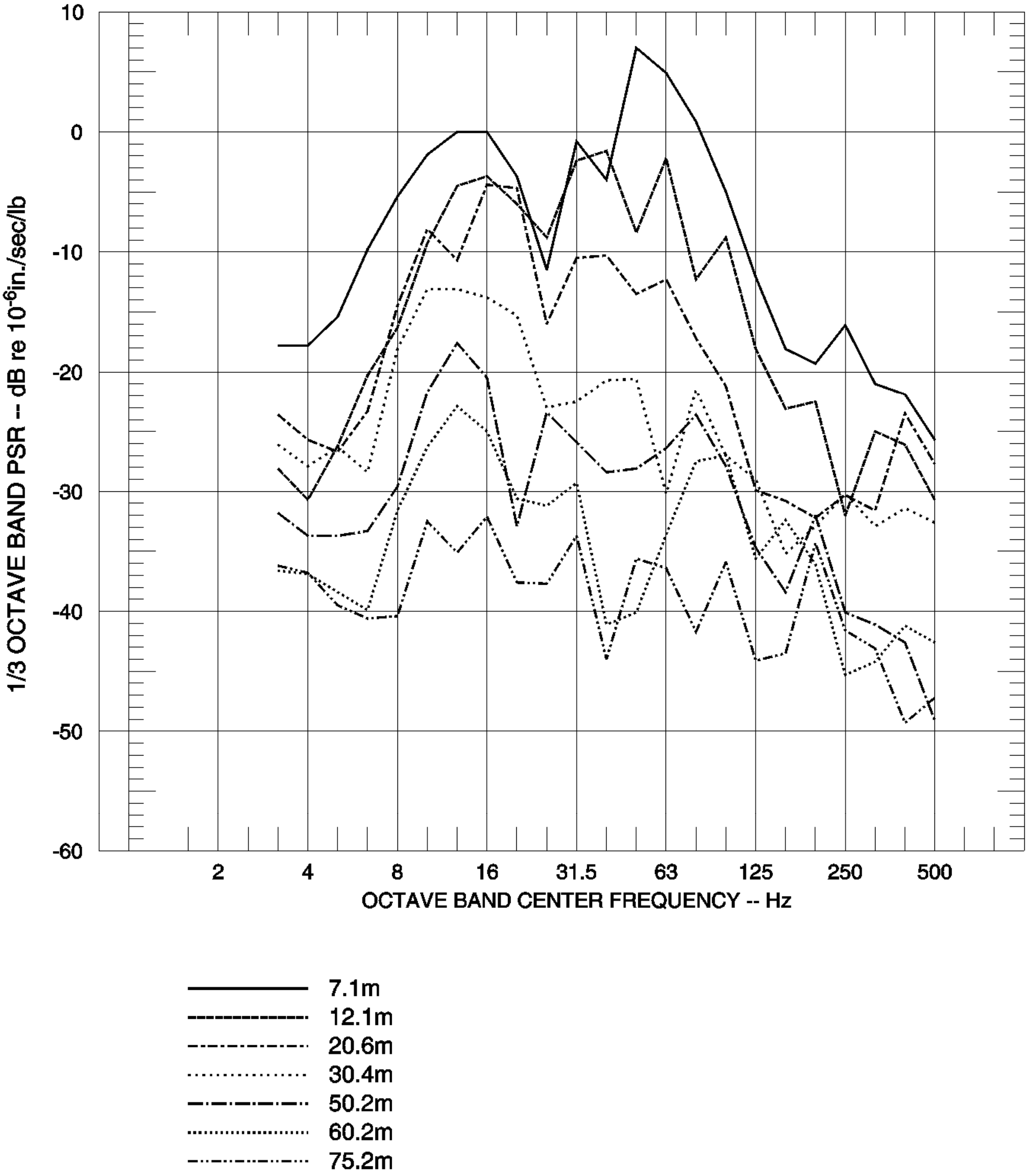

FIGURE 24 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D103 WITH THE DEPTH OF 12.9m

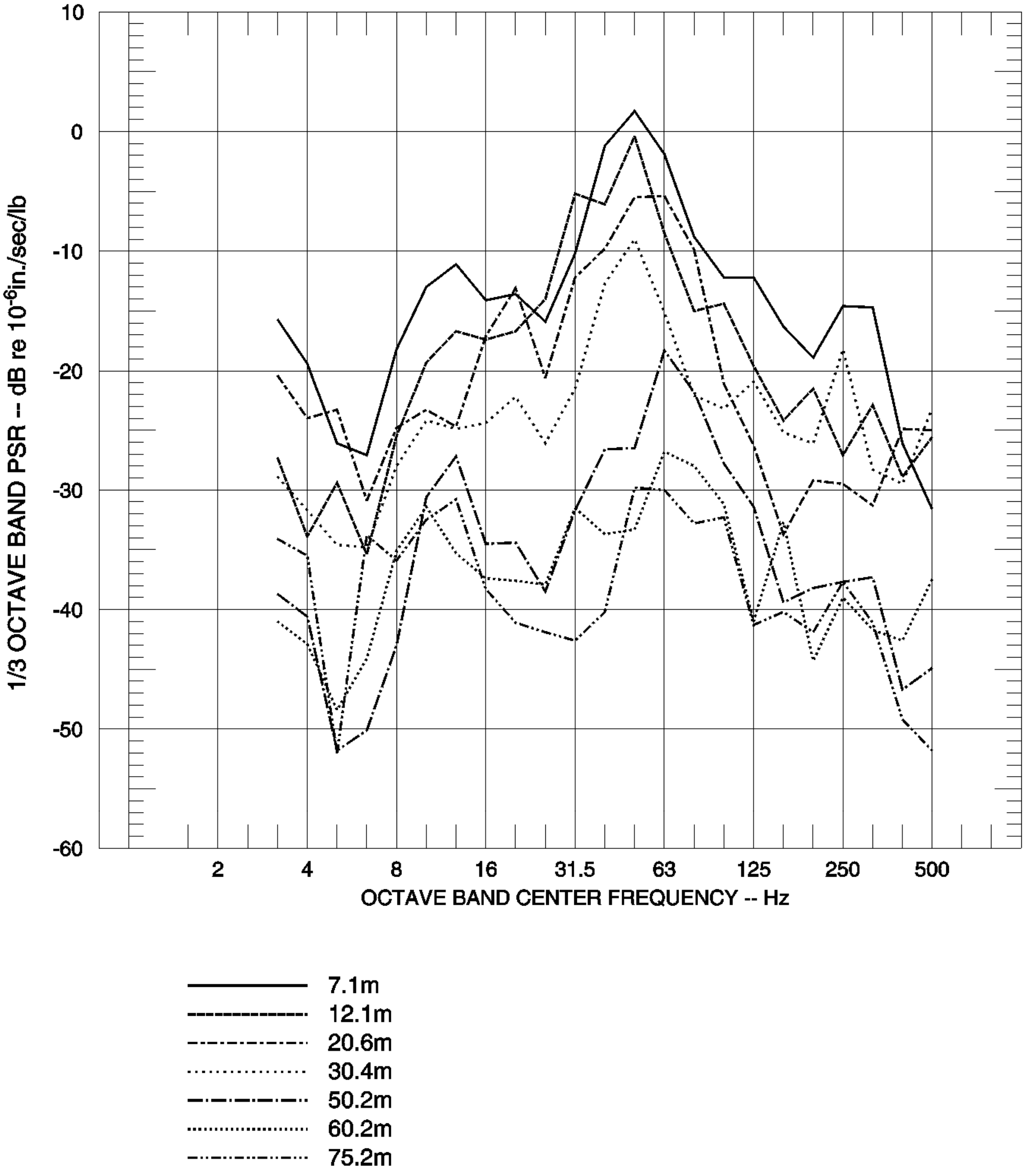

FIGURE 25 POINT SOURCE RESPONSE (PSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D103 WITH THE DEPTH OF 21m

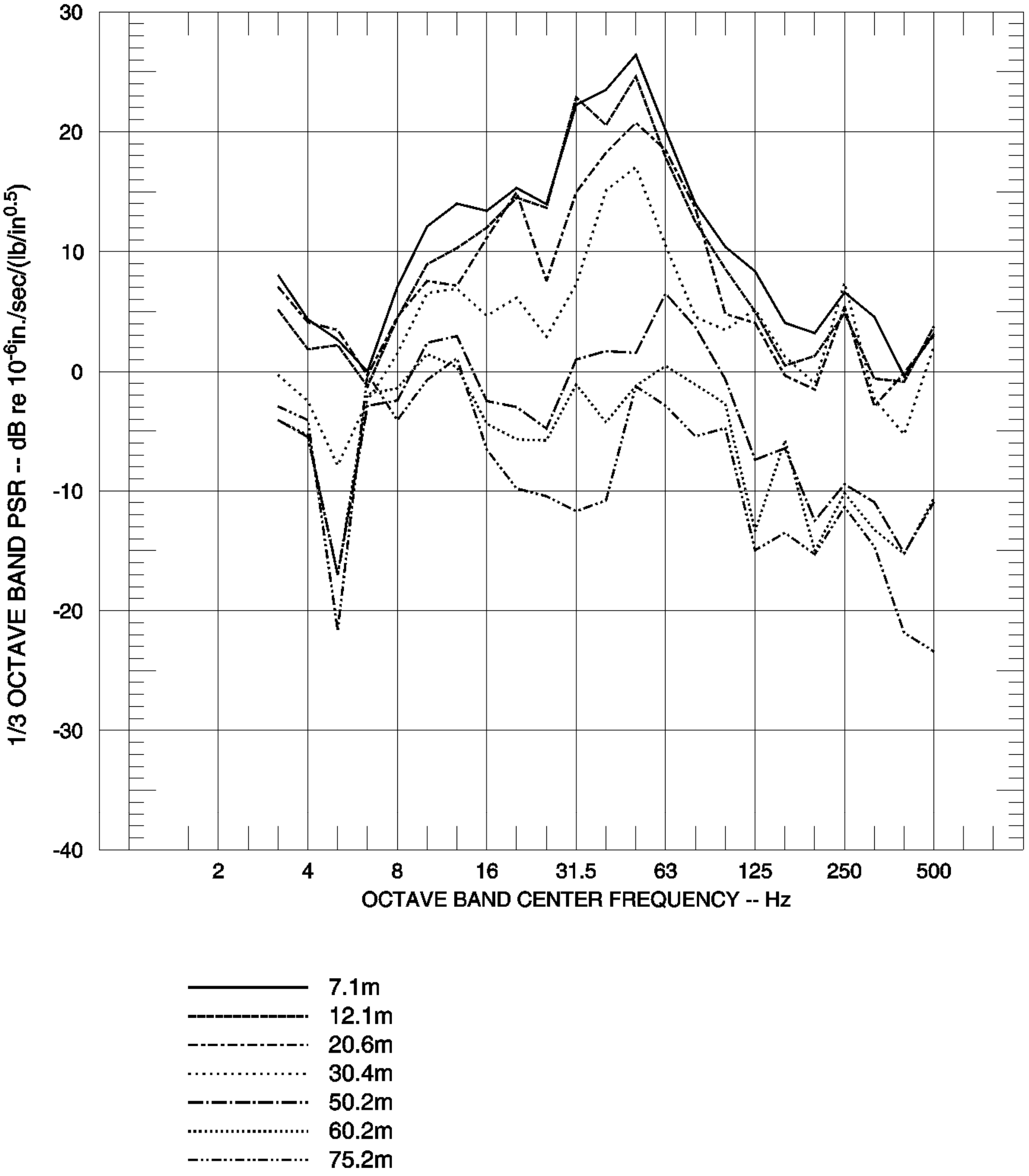

FIGURE 26 LINE SOURCE RESPONSE (LSR) AT VARIOUS SETBACKS FROM IMPACT BOREHOLE D103 WITH THE DEPTH OF 21m

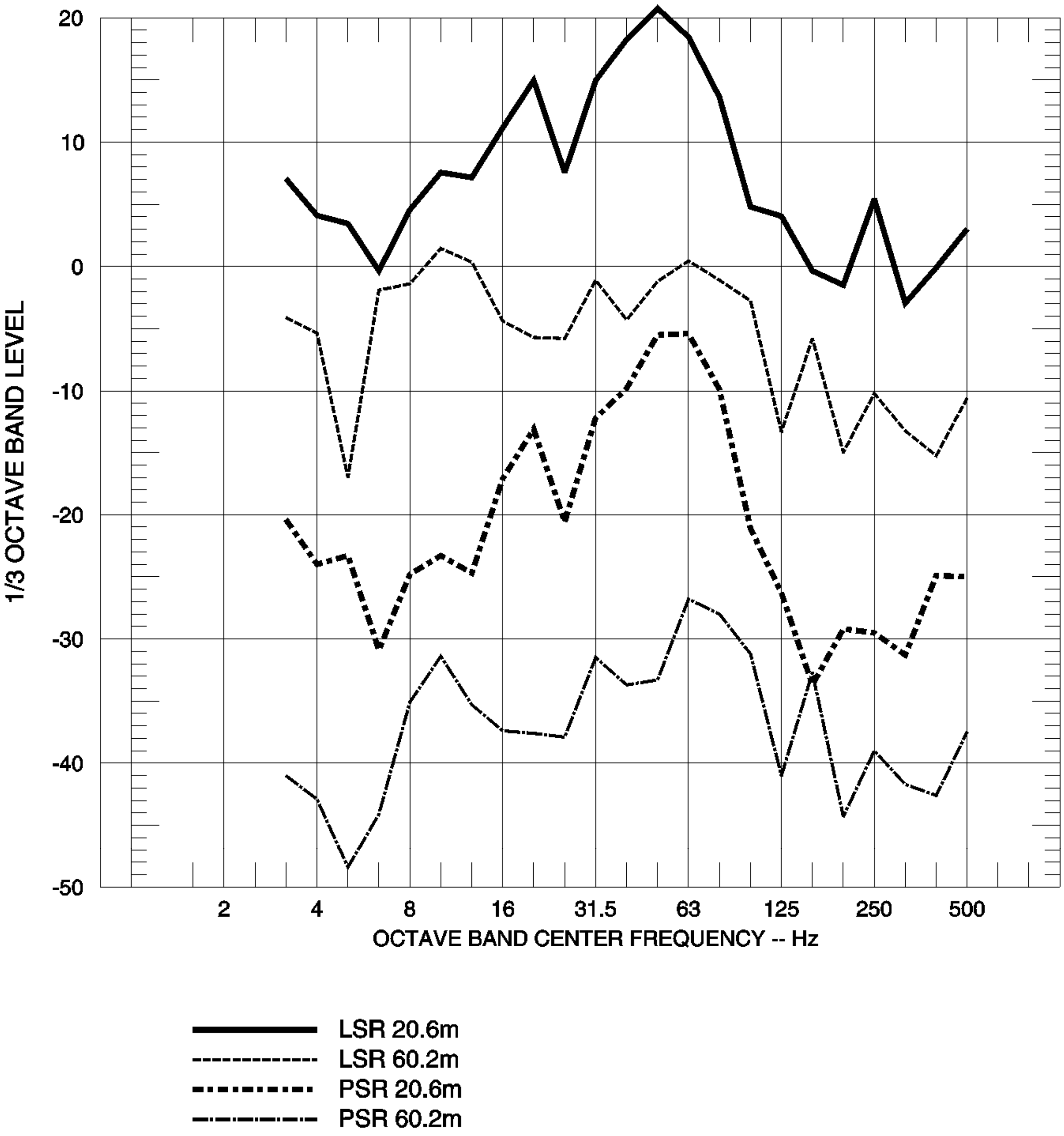

FIGURE 27 COMPARISON OF PSR AND LSR AT 20.6m AND 60.2m SETBACKS FROM IMPACT BOREHOLE D103 WITH THE DEPTH OF 21m