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ANALYSIS OF GROUND MOTION DATA AND PREDICTION TECHNIQUES FROM THE PRE-DICE THROW II EVENTS.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twenty-five experimenters and support agencies participated in the Pre-DICE THROW II program. This program consisted of two HE events, one using a 100-ton surface-tangent sphere of TNT and the other a 120-ton surface-tangent domed cylinder of bagged ANFO. The purpose of this report is to compare certain aspects of the ground-motion data with the predictions made of these aspects before the tests. Four agencies were charged with providing predictions: Air Force Weapons Laboratory (AFWL); Waterways Experiment

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20. ABSTRACT (Continued)

Station (WES); R and D Associates (RDA); and Field Command, DNA (FC). This report consists of seven chapters, which include: A brief description of the initiation of ground motion under a high-explosive detonation ground-motion transducers, canisters, grout and prediction methods; summaries of the data from Events 1 and 2 and comparisons of these with the predictions; analysis and authors' conclusions.

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CHAPTER 1

ELEMENTS OF GROUND MOTION

A. INTRODUCTION

Pre-DICE THROW II is a two-event series of high explosive tests performed at the White Sands Missile Range as a calibration for the main DICE THROW event. The purpose of the tests was to provide baseline data on the site geology (cratering and ground motion characteristics) and to compare results obtained using different explosives and charge configurations. The first event consisted of a 100-ton surface tangent sphere of TNT detonated by a single centrally located booster charge. It was fired on 12 August, 1975, and will be designated "Pre-DICE THROW II-1". The second consisted of a 120-ton surface tangent domed cylinder (length to diameter ratio 0.75) of ANFO (ammonium nitrate fuel oil mixture). Designation of the second event, fired on 22 September of the same year and detonated by seven boosters located at equal intervals along the vertical axis, will be Pre-DICE THROW II-2. The operation was conducted at Queen 15 site at the White Sands Missile Range, New Mexico, under the direction of Field Command, Defense Nuclear Agency.

Twenty-five experimenters and support agencies participated in the Pre-DICE THROW II program. The Preliminary Results Report (POR 6904) was published in September, 1976, and describes the entire operation, giving some test data in preliminary form. The Test Execution Report, (POR 6965), in preparation, will describe the as-built pre-test experiments in detail. Ground motion measurements will be published in a separate report by Waterways Experiment Station (WES), as will the results of all experiments by other agencies and laboratories.

The purpose of this report is to compare certain aspects (such as peak values) of the ground motion data with predictions made of these aspects before the tests. Four agencies were charged with providing predictions: the Air Force Weapons Laboratory (AFWL); Waterways

Experiment Station (WES); R and D Associates (RDA); and Field Command, DNA (FC). Making accurate predictions is essential to any test program in order to provide correct gage ranges so that useful data may be obtained, and prediction evaluation is a necessary function. Ground motion is a very complicated phenomenon for which there does not exist good quantitative understanding. Consequently, prediction evaluation becomes especially significant in this area.

This report consists of seven chapters. The first chapter includes a brief description of the initiation of ground motion under a high explosive detonation. The second chapter describes the ground motion transducers used in Pre-DICE THROW II and their outputs. Chapter Three discusses the prediction methods. Chapter Four presents a complete summary of data from Event 1 and compares the data with predictions; Chapter Five presents the same information for Event II. In Chapter Six, data from Events I and II are compared. Finally, Chapter Seven gives a short resumé of results and conclusions.

B. NATURE OF HE EXPLOSIONS

Different types of explosives have different physical detonation characteristics. In practical applications, the configuration and mode of initiation can also be important. Therefore, although the two pre-DICE THROW II charges, 100 tons of TNT and 120 tons of ANFO, had about the same energy yield, they may have produced somewhat different results on and in the ground. It is difficult to predict the differences. Gross (far field) effects are, of course, yield dependent and hence relatively insensitive to charge configuration. This point is discussed more fully in Chapter 6.

For both Pre-DICE THROW II events, the water table lay about 2 meters below the surface. The material properties of the soil differed slightly in the two cases, but the ground medium consisted primarily of horizontal layers of silt, clay, and sandy gravel down to 150 meters, the greatest depth explored. Layer thicknesses were of the order of tens of centimeters.

Craters in the two cases were alike and differed from the usual crater formation by being broad and shallow. Also, the lips of the craters appeared to be made up of relatively intact layers folded over. These craters give the impression that near-surface spalling occurred, which implies that certain rather specific conditions pertain. Development of a low pressure region behind the air shock wave, coupled with the bouyant motion of the fireball, can elevate loose material in the spalled layer, leading to the well-known crown of jets and subsequent throw-out of spalled material.

The effects which produce the crater demonstrate by their violence that a very strong wave is propagated into the ground directly from the explosive region. This wave is often called the "crater-induced" ground wave, or more correctly the "direct ground wave". When the explosive charge is in contact with the ground, the ground wave is initiated simultaneously with the air wave.

Certain differences between the craters of Events 1 and 2 suggest that different modes of coupling the ground wave into the ground medium were predominant in the two cases. In particular, the flat bottom of the Event 1 crater was about 2 meters <u>below</u> the water table, while the flat bottom of the Event 2 crater was just <u>at</u> the water table. The presence of the water table and the influence it had on crater formation was significant, but it alone does not determine the level of spallation. Examination of the early fireball photographs (POR 6917) shows that the area of the fireball in contact with the ground grows relatively faster for Event 2 than for Event 1, suggesting that the crater for Event 2 may have the larger diameter, as it does.

Even though our understanding of how the crater is formed is incomplete, it is obvious that a powerful compression wave is sent into the ground at the same time the blast wave is propagated in air. In air, which is very compressible, a shock wave forms which moves supersonically. In the ground, which is relatively incompressible, a shock wave typically does not form (or if it does, it quickly dies out). The propagation of energy in the ground is by elastic and plastic waves, and is much more complex in nature than the propagation of the shock in air.

The movement of the blast (shock) wave across the surface compresses the ground and, if the speed of the air wave exceeds that of an acoustic wave in the ground, then another compression wave will be produced in the ground. This wave is called the "airblast induced ground wave". As long as the necessary conditions exist at the surface, it will be produced in the ground.

As the airblast wave advances, it weakens and slows down (because it is a shock). Elastic ground waves travel at constant speed. Therefore, the ground wave eventually overtakes and outruns the air wave. The radius of overtaking is called the "crossover", and the area beyond the crossover is called the "outrunning region".

There are several other waves produced in the ground: shear waves and surface waves exist, as do multiple reflections of compression waves. They all show up on the ground motion records. However, for present purposes, they will be neglected. They do not seem to play significant roles in close-in ground motion phenomenology.

C. WAVE CONFIGURATION IN THE GROUND

It is clear from the preceding discussion that the ground motion can become very complex. However, the objectives of the Pre-DICE THROW II ground motion experiments were to measure accurately the relationships between the main airblast induced ground wave and the main direct ground wave. Thus a very much simplified situation can be depicted.

The first drawing (Figure 1.1) shows an idealized situation in which the ground is a homogeneous half-space. Obviously, as long as the airblast wave travels faster than the ground wave, there will be a depth above which an instrument will record first the airblast induced wave and then the ground wave. At a greater depth, the relative positions of the two waves on the record will be reversed. When the direct ground wave leads the airblast wave, then there cannot be an airblast induced ground wave because the airblast wave is no longer supersonic relative to the ground.

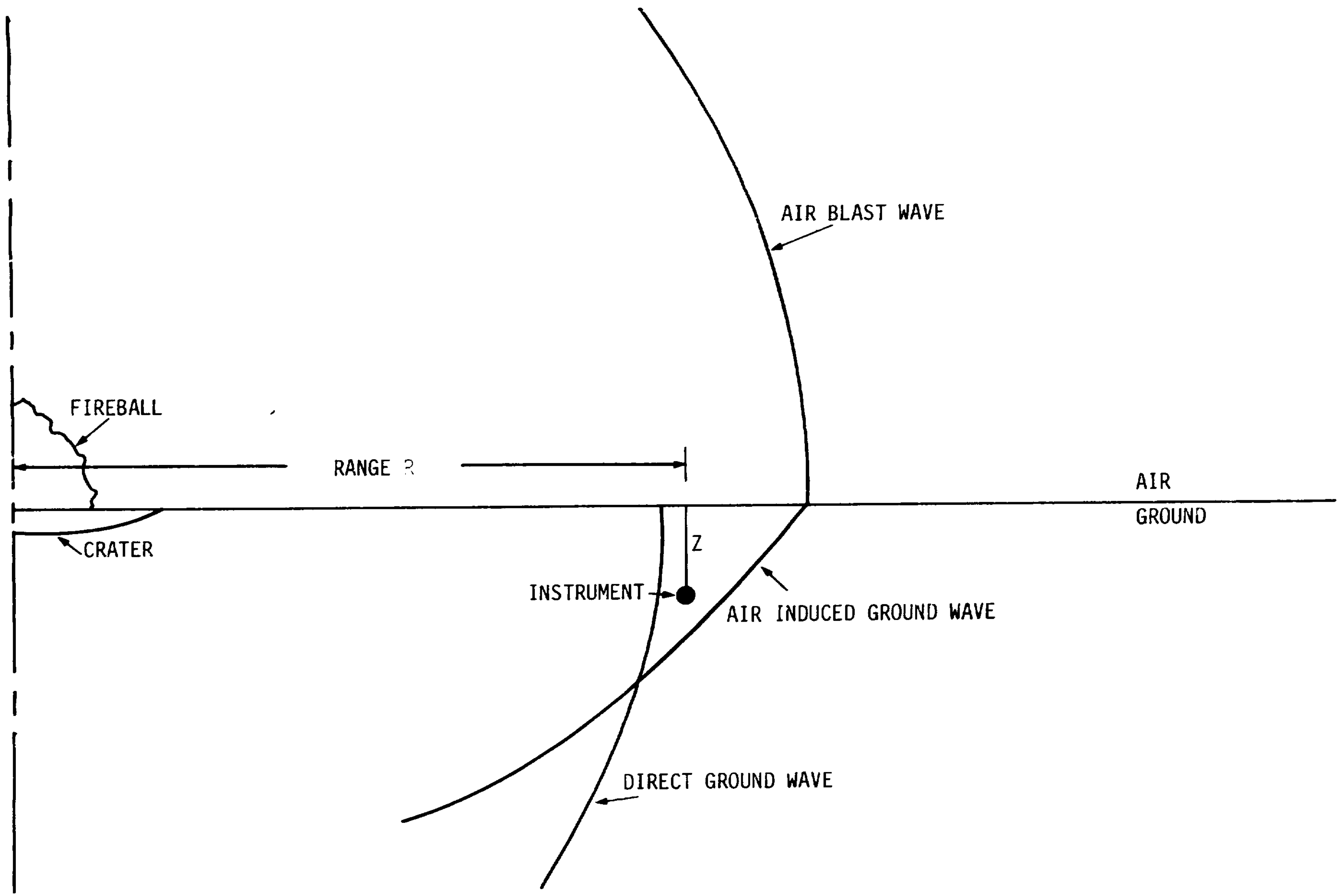

Figure 1.1. Configuration and Definitions

The second drawing (Figure 1.2) shows the effect of introducing a surface layer in which the wave propagation velocity is low. Here the situation is more complex. In particular, it now becomes possible for an instrument to observe both air- and ground-induced waves in the low velocity layer; and their relative positions can be exchanged either by locating two instruments at different depths and the same range, or at different ranges and the same depth. Some examples will be given in the next section.

Note, too, that there is a range, in the case of the low velocity surface layer, where the direct ground wave can outdistance the air wave (Figure 1.2), but there will still be an airblast induced ground wave. Since low velocity surface layers are the common in geological profiles of interest, the situation depicted in Figure 1.2 is a familiar one and the cross-over range is a characteristic of most explosions. The range at which crossover occurs can often be calculated quite accurately.

It is clear from Figure 1.2 that the air- and ground-induced wave fronts always have opposite inclinations for the case of a slow layer over a faster layer. The radial (or horizontal) components of these wave motions are generally directed outward and are difficult to distinguish. The vertical components, on the other hand, are oppositely directed: the air-induced motion is always downward and the ground-induced motion is always upward. Therefore, the vertical components immediately identify the relative arrival times of the two induced waves.

D. INSTRUMENT RESPONSES

Instruments (particularly velocity gages), when placed at any of the positions indicated in Figures 1.1 and 1.2, will respond to the vector sum of all wave motions. Velocity gages made to respond only to motion along their principal axes will, of course, give records indicating the algebraic addition of wave components along those axes. Consequently the vertical component gage will show strong positive and

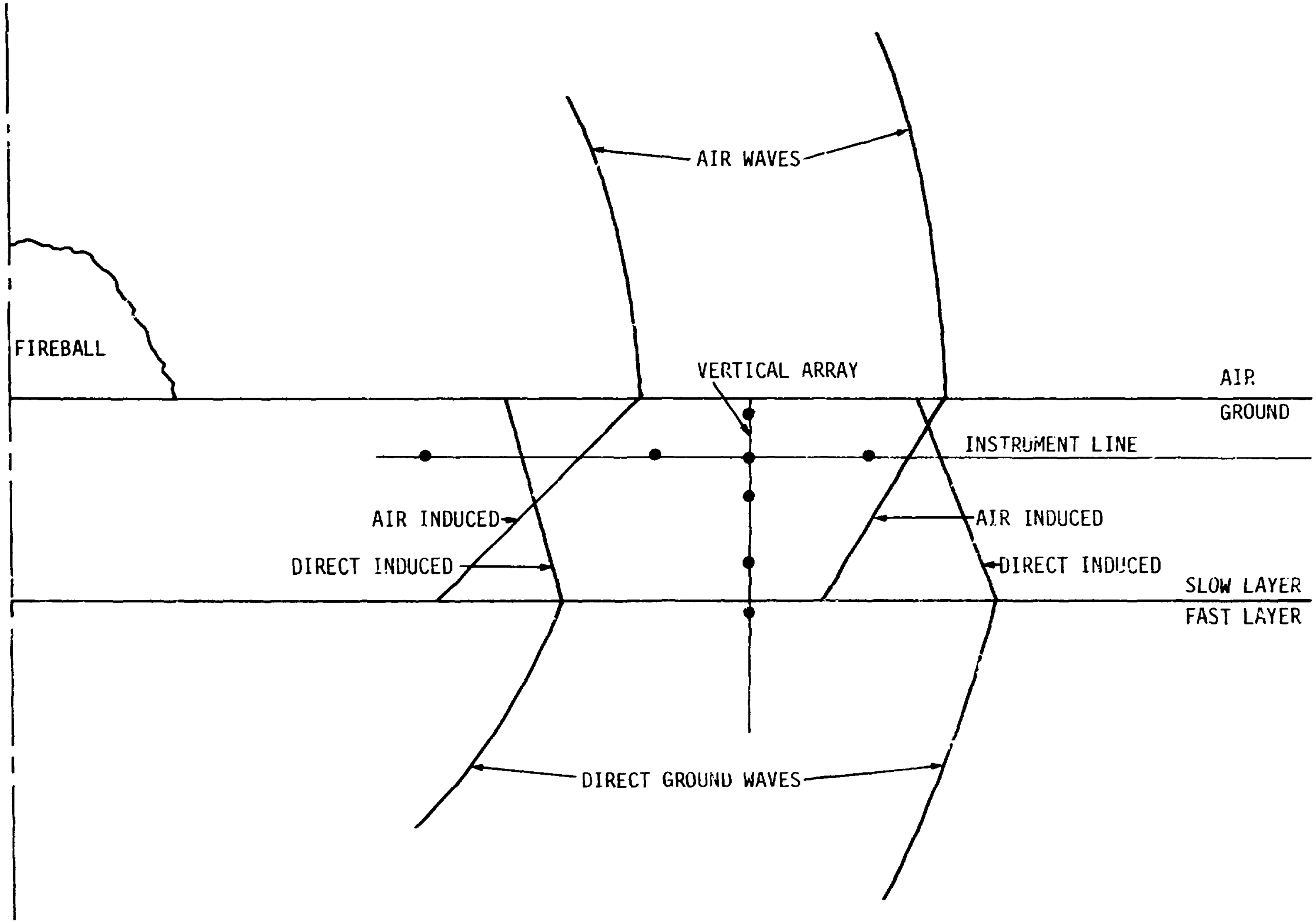

Figure 1.2. Effect of a Slow Surface Layer

negative excursions, while the radial (horizontal) component gage will show mostly positive excursions. Since the real situation consists of many wavelets of different types moving in many directions, the gage record can be very complicated.

In an effort to simplify the picture but still retain essentials, Figure 1.3 shows schematically the algebraic summation of the vertical and horizontal components of both the air- and ground-induced waves at one of the instrument positions of Figure 1.2. The heavy solid line represents, in each case, the algebraic resultant of the two vertical and two horizontal components, respectively.

When reducing the data, the maxima, minima, and inflection points are read off the gage record. Notice that they do not represent true peak values. Some effort is made to compensate for the unavoidable error by reading excursions from the previous inflection point rather than from the baseline. Nevertheless, there are inherent in the data reduction techniques some defects which tend to underestimate the vertical component peaks; and first to underestimate, then overestimate the radial component peaks. Consequently, theoretical calculations which determine the induced wave forms separately may be accurate yet not compare well with the experiment. And by the same argument, good agreement between prediction and measurement is not necessarily confirmation of the prediction technique because of problems of superposition.

Figure 1.4 illustrates the principles shown in Figures 1.2 and 1.3. At the same depth (namely 0.5 meter) but at two different ranges, the air- and ground-induced vertical components of velocity change places. The interchange cannot be detected on the radial (horizontal) waveforms, although the two waves are observable. These waveforms are traced from Figures 4.49, 4.50, 4.61 and 4.62 of Chapter 4.

Referring to Figure 1.2 once more, it is obvious that at a given range, the same sequence of change in the vertical component can be found in an array of instruments arranged vertically. Figure 1.5 illustrates the vertical array concept. These waveforms were traced

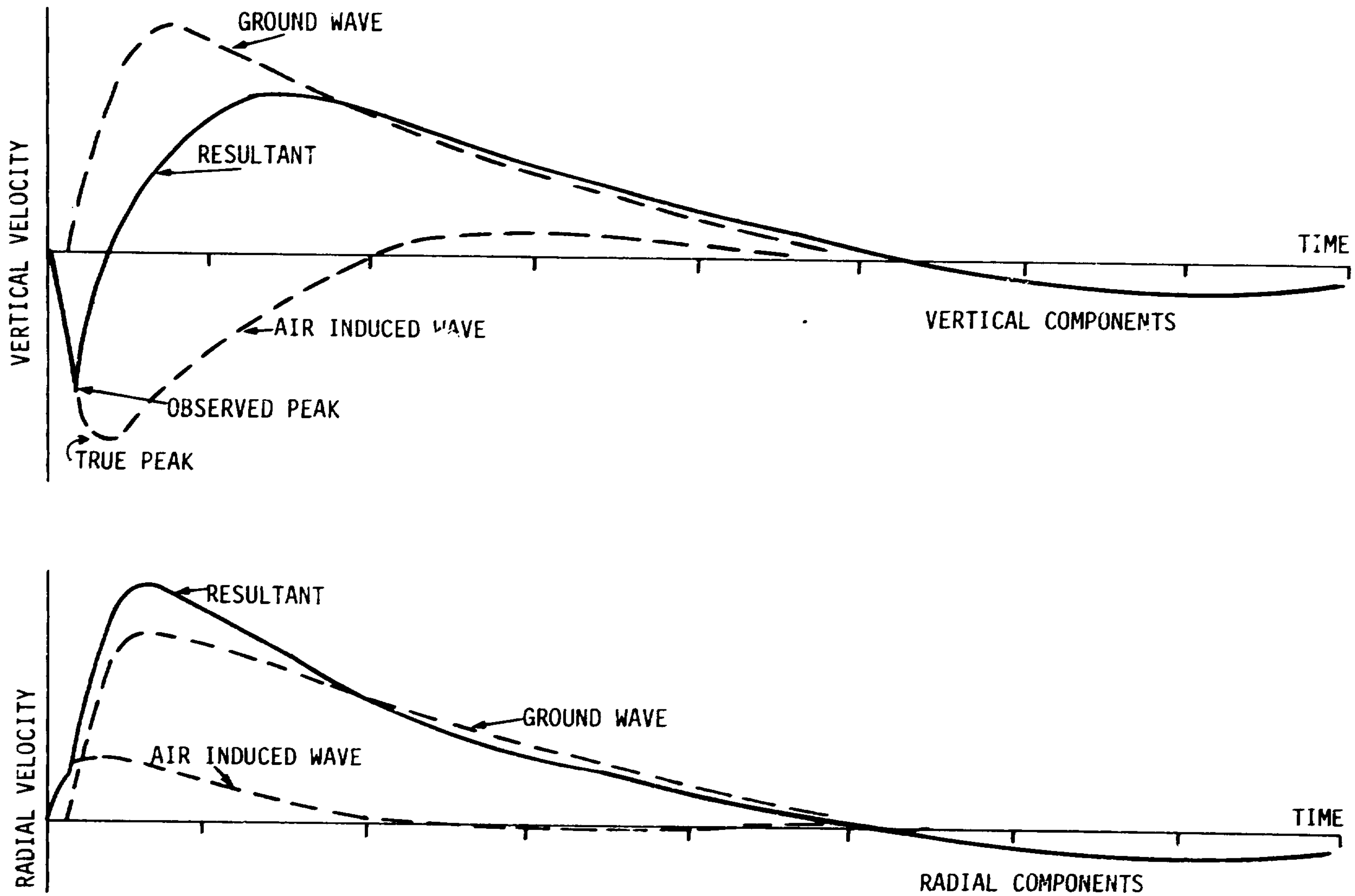

Figure 1.3. Idealized Wave Forms

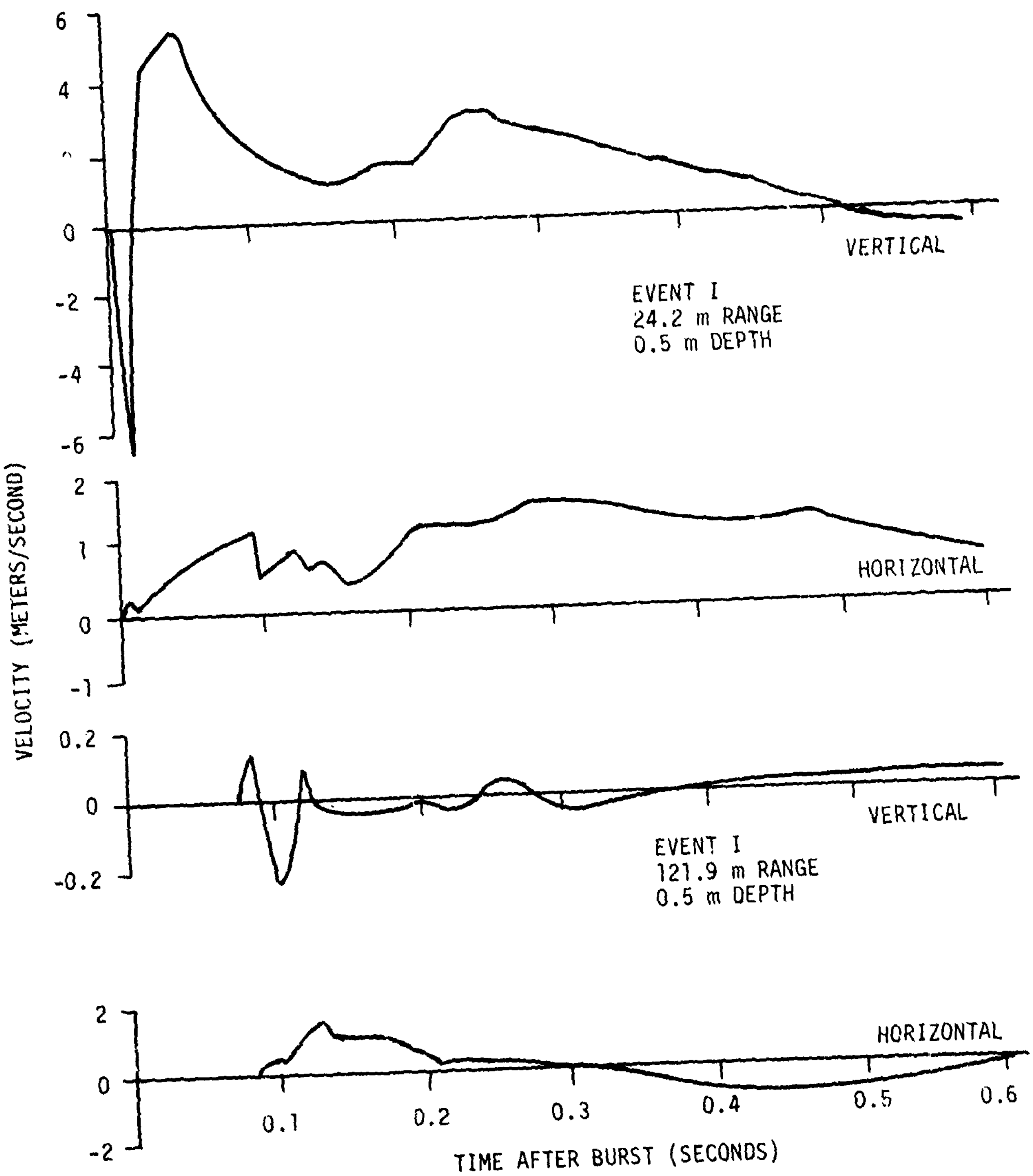

Figure 1.4. Realistic Wave Forms, Event I

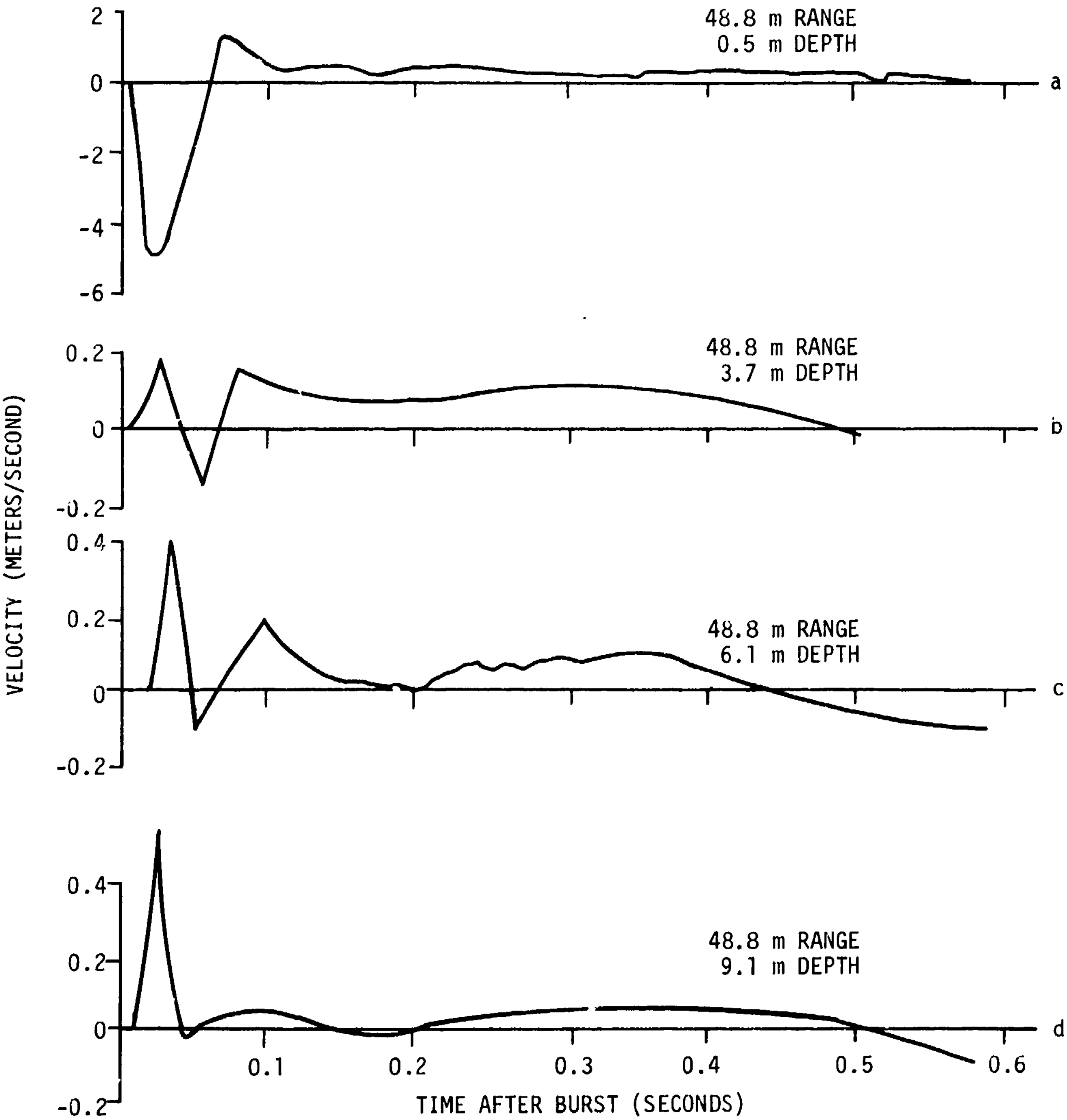

Figure 1.5. Realistic Wave Forms, Vertical Components at Various Depths, Event 1

from Figures 4.51, 4.53 and 4.55 of Chapter 4. In the upper wave form (a, at 0.5 meter depth), the air-induced ground wave predominates. In wave form b (at 3.7 m depth), the direct induced ground wave is beginning to lead. In wave form c (at 6.1 m depth), the direct induced ground wave now predominates; and in wave form d (at 9.1 m depth), the air-induced ground wave has essentially disappeared. Perhaps the boundary between the slow and fast media lies at or above the 9.1 meter level.

The features which have just been described are mainly characteristics of the slow layer. As long as the induced waves form an "X" in the slow layer as shown in Figure 1.2, these features will be seen. Eventually the air wave falls behind the ground wave and the "X" can no longer form.

The air-induced wave in the slow layer must, of course, intersect the slow-fast interface. This was omitted from Figure 1.2 for simplicity. At the slow-fast interface, the air-induced wave will be both reflected and refracted. The refracted wave will penetrate the fast layer, but the laws of elastic refraction dictate that the transmitted wave be relatively weak. Therefore, the slow layer tends to isolate the region beneath it from the air-induced wave, and this can be seen by examination of Figure 1.5.

E. RELATIONS TO PREDICTIONS

Four prediction techniques will be discussed in some detail in Chapter 3. Here we deal in generalities.

Predictions which separately calculate the air- and direct-induced wave shapes by hydrocode or some other method based on first principles, but do not combine them in proper phase, can be expected to overpredict peak values for vertical velocity components and to underpredict peak values for radial (horizontal) velocity components. This is illustrated in Figure 1.3.

If such predictions include combining the air- and direct-induced wave shapes in proper phase, then the predictions will be very sensitive to the integral of the propagation velocities over the full ray paths of both the airblast wave and the direct ground wave.

Prediction techniques based on results from other tests may give excellent or absurd results depending on charge configuration and geologic similarity considerations.

It will be shown in Chapters 4 and 5 that predictions of phase relations between air- and direct-induced waves were not very successful. Predictions of peak values versus distance were in fairly good agreement with measured peak values when phase was ignored. The first statement attests to the difficulty of integrating along the ray path. The second statement attests to the generally similar nature of these field tests to others performed over media of approximately the same geologic profile.

CHAPTER 2

GROUND MOTION DATA ACQUISITION TECHNIQUE

A. INTRODUCTION

The first event (TNT) on Pre-DICE THROW II had the most ground motion instrumentation. There were a total of 78 channels of acceleration measurements and 110 channels of velocity measurements. The second event (ANFO) had 32 channels of acceleration and 72 channels of velocity measurements. A break-out of gage placement for each event is shown in Tables 2.1 through 2.4. Figures 2.1 and 2.2 indicate the placement pattern surrounding ground zero for each event and Figures 2.3 and 2.4 depict the gage placement profiles (range and depth) for each event.

Additional radials (60, 180, and 300 degrees) were instrumented on the TNT event at the 33.5-meter range to examine test-bed azimuthal symmetry.

B. TRANSDUCERS AND THEIR SYSTEMS

1. Accelerometers

Endevco piezoresistive accelerometers were used on both events. The different models used were chosen for the following reasons:

a. The gage's range is selected so that it is 4 to 10 times greater than the set range or predicted level of acceleration. This is done for several reasons: (1) the h[illegible]er the gage's range, the higher is its frequency response; (2) above [illegible] percent of the gage's range, the outputs are sufficient to give a good signal to noise ratio; and (3) additional insurance is provided against overranging.

b. Due to lead-time requirements by the manufacturer, the order for the gages was placed based on preliminary ground motion predictions. Up-dating of these predictions caused, in some cases, rearrangement of the gages to different locations more appropriate to their range.

c. The miniature model 2264 gages were used in the close-in region because of their high natural frequency. These gages were housed in micro canisters, which increases the overall natural frequency of the system.

The overall system schematic used for accelerometer channels is shown in Figure 2.5. The data analysis techniques will be discussed later.

2. Velocity Gages

The velocity gages used were versions of the Sandia DX gage and were manufactured by Consolidated Electrodynamics Corporation and Sparton Southwest, Inc. Only two types of these gages were used. In general, the close-in gages had smaller sensing armatures, thereby giving them a lower sensitivity. All of the gages were damped using 1000 cs damping fluid. The system schematic, shown in Figure 2.5, also applies to the velocity measurements.

3. Canisters

The three types of canisters used by WES for housing the ground motion transducers are called "micro", "mini" and "standard". The "micro" and "mini" canisters are used exclusively for housing accelerometers, and the "standard" canister can contain two velocity gages and two accelerometers. The fill or potting material used inside the canisters is a polyurethane-based thermosetting resin called Biwax 601. A design and evaluation discussion on these canisters is found in Reference 1.

4. Grout

All ground motion canisters were fixed in place in boreholes with a "quick-set" grout. A plug of this grout, roughly 0.61 m long, and extending from about 0.30 m below canister center to 0.30 m above it, was used. A filler grout, designated WES grout E-2-E, was used

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[1] Ground Motion Canister Design and Evaluation, Andres Peekna, U.S. Army Engineer Waterways Experiment Station Corps of Engineers, Vicksburg, Mississippi.

between gages, and to top out deep (3.7 m and greater) canister holes. Shallow (1.8 m and less) holes were topped out with local top-soil backfill. Some properties of the grouts mentioned are:

	Quick Set		E-2-E	
Density	2026.3 kg/m^3		2023.1 kg/m^3	
Unconfined Compressive Strength	13,800-20,700 kPa		690-1035 kPa	
Mix Components (for 0.30 m^3 batch)	Chem Stress Cement	5.7 kg	Portland Cement	5.6 kg
	Cal-Seal Cement	17.2 kg	Bentolite Gel	2.1 kg
	Sand	22.9 kg	Barite	8.3 kg
	Water	11.5 kg	Sand	28.5 kg
			Water	12.8 kg

5. Gage Emplacement

A special placement rod was used to lower the gage canisters into the holes. Each section of this rod was 0.30 m in length. The rods and canister had alignment marks which were aligned throughout the lowering process. When the canister was at the proper depth, a 4-power scope was attached to the top rod and alignment with ground zero was made. This alignment was maintained during the grouting process.

The accelerometer canisters were aligned vertically and horizontally using the assumption that the holes were vertical (WES feels that their canisters were within 2 to 3 degrees from vertical). The errors in gage output due to alignment are negligible if this degree of alignment accuracy is maintained.

Since the velocity gage is extremely sensitive with respect to horizontal and vertical orientations, a bubble table was used prior to canister emplacement. The canister was mounted on the table, and the electrical zero of each gage was determined. After the canisters were lowered, this same electrical zero was maintained during grouting. The deviations from true vertical or horizontal were maintained at less than 1/4 degree.

C. METHOD USED BY WES TO REDUCE DATA

1. Accelerometer Data

On horizontal acceleration data, the outward peak (away from ground zero) was normally taken as the peak acceleration. For vertical acceleration, the absolute value of the largest peak in either direction was taken as the peak value.

The raw data was digitized at the rate of 24,000 samples per second. No filtering was used.

2. Velocity Gage Data

The outward peak motion was chosen for the horizontal velocity peak value. The inward peak (toward ground zero) was considered as an elastic recovery of material and was normally less than the outward excursion. Two values were read from the vertical velocity records, the downward directed airblast induced peak and the positive peak caused by direct or crater induced ground motion. Selecting or interpreting these values prior to the outrunning region was relatively straightforward; however, for those data at ranges just past outrunning the task was more difficult, sometimes requiring large expansions (in time) of the waveform in order to discern the change in slope of the data. The values chosen for peaks are not necessarily measured from zero, but are taken from the point where the airblast induced velocity starts to influence the waveshape caused by the ground motion induced portion. As discussed in Chapter 1, some error in inevitable using this method if direct and airblast induced motions are superimposed.

3. Record Quality

Peak data was not obtained from 21 accelerometers on Event 1, and 5 accelerometers on Event 2. In most cases this was because the cables or cable/transducer interfaces were destroyed prior to peak arrival. Band edge was exceeded on 16 records on Event 1 and 12 records on Event 2. Table 2.5 gives specific locations of those gages from which band edge data or records indicating cable destruction were obtained. Note that all gages in the band edge category are below the water table.

Six vertical velocity gages went to band edge on Pre-DICE THROW II, Event 1. Five of these were at the 48.8-m range on all three main gage radials. They went out of band edge on the negative peaks (airblast induced) only and subsequent portions of the wave forms were within band edge. The depth of these gages was 0.5 to 1.8 meters.

The signal conditioning for similar gages on Event 2 was changed so that the gage overranging would not occur.

Table 2.1. Pre-DICE THROW II, Event 1

ACCELEROMETER IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Gage Model**	Gage Range	Set Range (g's)	Canister Type
0	12.2	0.5	V	2264	30 kg	10 kg	Micro
0	12.2	0.5	H	2264	20 kg	5.5 kg	Micro
0	12.2	1.8	V	2264	20 kg	10 kg	Micro
0	12.2	1.8	H	2264	20 kg	4.5 kg	Micro
0	12.2	3.7	V	2264	30 kg	10 kg	Micro
0	12.2	3.7	H	2264	20 kg	4.5 kg	Micro
0	18.3	0.5	V	2264	5 kg	2.3 kg	Micro
0	18.3	0.5	H	2264	5 kg	1.3 kg	Micro
0	18.3	1.8	V	2264	5 kg	2 kg	Micro
0	18.3	1.8	H	2264	5 kg	1.1 kg	Micro
0	18.3	3.7	V	2261M6	10 kg	2 kg	Mini
0	18.3	3.7	H	2261M6	10 kg	1.1 kg	Mini
0	18.3	6.1	V	2261M6	10 kg	2 kg	Mini
0	18.3	6.1	H	2261M6	10 kg	1.1 kg	Mini
0	18.3	9.1	V	2261M6	10 kg	2 kg	Mini
0	18.3	9.1	H	2261M6	10 kg	1.1 kg	Mini
0	9.1	3.7	V	2261C	2.5 kg	700 g	Mini
0	9.1	3.7	H	2261C	2.5 kg	400 g	Mini
0	24.4	6.1	V	2261C	2.5 kg	700 g	Mini
0	24.4	6.1	H	2261C	2.5 kg	400 g	Mini
0	24.4	9.1	V	2261C	2.5 kg	700 g	Mini
0	24.4	9.1	H	2261C	2.5 kg	400 g	Mini
0	24.4	12.2	V	2261C	2.5 kg	700 g	Mini
0	24.4	12.2	H	2261C	2.5 kg	400 g	Mini
0	24.4	18.3	V	2261C	2.5 kg	700 g	Mini
0	24.4	18.3	H	2261C	2.5 kg	400 g	Mini
0	33.5	0.5	V	2261C	2.5 kg	300 g	Std.
0	33.5	0.5	H	2261C	2.5 kg	170 g	Std.

Table 2.1. Pre-DICE THROW II, Event 1 (Continued)

ACCELEROMETER IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Gage Model**	Gage Range	Set Range (g's)	Canister Type
0	33.5	3.7	V	2262C	1 kg	200 g	Std.
0	33.5	3.7	H	2262C	200 g	150 g	Std.
0	33.5	6.1	V	2261C	2.5 kg	200 g	Mini
0	33.5	6.1	H	2262C	200 g	150 g	Mini
0	33.5	9.1	V	2261C	2.5 kg	200 g	Mini
0	33.5	9.1	H	2262C	200 g	150 g	Mini
0	33.5	12.2	V	2261C	2.5 kg	200 g	Mini
0	33.5	12.2	H	2262C	200 g	150 g	Mini
0	48.8	0.5	V	2262C	1 kg	140 g	Std.
0	48.8	0.5	H	2262C	200 g	45 g	Std.
0	48.8	3.7	V	2262C	200 g	75 g	Std.
0	48.8	3.7	H	2262C	200 g	40 g	Std.
0	91.4	0.5	V	2262C	200 g	60 g	Std.
0	91.4	0.5	H	2262C	200 g	15 g	Std.
0	91.4	1.8	V	2262C	200 g	25 g	Std.
0	91.4	1.8	H	2262C	25 g	8 g	Std.
0	91.4	3.7	V	2262C	200 g	25 g	Std.
0	91.4	3.7	H	2262C	25 g	8 g	Std.
0	91.4	6.1	V	2262C	200 g	25 g	Std.
0	91.4	6.1	H	2262C	25 g	8 g	Std.
60	33.5	3.7	V	2262C	1 kg	200 g	Mini
60	33.5	3.7	H	2262C	200 g	150 g	Mini
120	18.3	0.5	V	2264	5 kg	2.3 kg	Micro
120	18.3	0.5	H	2264	5 kg	1.3 kg	Micro
120	24.4	3.7	V	2261C	2.5 kg	700 g	Mini
120	24.4	3.7	H	2261C	2.5 kg	400 g	Mini

Table 2.1. Pre-DICE THROW II, Event 1 (Continued)

ACCELERATION IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Gage Model**	Gage Range	Set Range (g's)	Canister Type
120	24.4	6.1	V	2261C	2.5 kg	700 g	Mini
120	24.4	6.1	H	2261C	2.5 kg	400 g	Mini
120	24.4	9.1	V	2261C	2.5 kg	700 g	Mini
120	24.4	9.1	H	2261C	2.5 kg	400 g	Mini
120	33.5	3.7	V	2262C	1 kg	200 g	Mini
120	33.5	3.7	H	2262C	200 g	150 g	Mini
120	33.5	6.1	V	2261C	2.5 kg	200 g	Mini
120	33.5	6.1	H	2262C	200 g	150 g	Mini
180	33.5	3.7	V	2262C	1 kg	200 g	Mini
180	33.5	3.7	H	2262C	200 g	150 g	Mini
240	18.3	0.5	V	2264	5 kg	2.3 kg	Micro
240	18.3	0.5	H	2264	5 kg	1.3 kg	Micro
240	24.4	3.7	V	2261C	2.5 kg	700 g	Mini
240	24.4	3.7	H	2261C	2.5 kg	400 g	Mini
240	24.4	6.1	V	2261C	2.5 kg	700 g	Mini
240	24.4	6.1	H	2261C	2.5 kg	400 g	Mini
240	24.4	9.1	V	2261C	2.5 kg	700 g	Mini
240	24.4	9.1	H	2261C	2.5 kg	400 g	Mini
240	33.5	3.7	V	2262C	1 kg	200 g	Mini
240	33.5	3.7	H	2262C	200 g	150 g	Mini
240	33.5	6.1	V	2261C	2.5 kg	200 g	Mini
240	33.5	6.1	H	2262C	200 g	150 g	Mini
300	33.5	3.7	V	2202C	1 kg	200 g	Mini
300	33.5	3.7	H	2262C	200 g	150 g	Mini

* H - Horizontal
V - Vertical
** Manufactured by Endevco

Table 2.2. Pre-DICE THROW II, Event 1

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
0	24.4	0.5	V	L-1	5.5	Std.
0	24.4	0.5	H	L-1	3.5	Std.
0	24.4	0.5	T	L-1	3.5	Std.
0	24.4	1.8	V	L-1	3.7	Std.
0	24.4	1.8	H	L-1	3.5	Std.
0	33.5	0.5	V	L-1	3.0	Std.
0	33.5	0.5	H	L-1	1.8	Std.
0	33.5	1.8	V	L-1	2.1	Std.
0	33.5	1.8	H	L-1	1.8	Std.
0	33.5	3.7	V	L-1	1.5	Std.
0	33.5	3.7	H	L-1	1.8	Std.
0	48.8	0.5	V	H-1	1.5	Std.
0	48.8	0.5	H	H-1	0.82	Std.
0	48.8	1.8	V	H-1	1.1	Std.
0	48.8	1.8	H	H-1	0.82	Std.
0	48.8	3.7	V	H-1	0.76	Std.
0	48.8	3.7	H	H-1	0.82	Std.
0	48.8	6.1	V	H-1	0.49	Std.
0	48.8	6.1	H	H-1	0.82	Std.
0	48.8	9.1	V	H-1	0.30	Std.
0	48.8	9.1	H	H-1	0.82	Std.
0	70.1	0.5	V	H-1	0.76	Std.
0	70.1	0.5	H	H-1	0.43	Std.
0	70.1	0.5	T	H-1	0.43	Std.
0	70.1	1.8	V	H-1	0.55	Std.
0	70.1	1.8	H	H-1	0.43	Std.
0	70.1	3.7	V	H-1	0.40	Std.

Table 2.2. Pre-DICE THROW II, Event 1 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
0	70.1	3.7	V	H-1	0.40	Std.
0	70.1	3.7	H	H-1	0.43	Std.
0	70.1	6.1	V	H-1	0.27	Std.
0	70.1	6.1	H	H-1	0.43	Std.
0	91.4	0.5	V	H-1	0.49	Std.
0	91.4	0.5	H	H-1	0.21	Std.
0	91.4	1.8	V	H-1	0.37	Std.
0	91.4	1.8	H	H-1	0.21	Std.
0	91.4	3.7	V	H-1	0.26	Std.
0	91.4	3.7	H	H-1	0.21	Std.
0	91.4	6.1	V	H-1	0.17	Std.
0	91.4	6.1	H	H-1	0.21	Std.
0	121.9	0.5	V	H-1	0.40	Std.
0	121.9	0.5	H	H-1	0.18	Std.
0	121.9	1.8	V	H-1	0.30	Std.
0	121.9	1.8	H	H-1	0.14	Std.
0	121.9	3.7	V	H-1	0.22	Std.
0	121.9	3.7	H	H-1	0.12	Std.
0	121.9	6.1	V	H-1	0.15	Std.
0	121.9	6.1	H	H-1	0.12	Std.
0	121.9	9.1	V	H-1	0.12	Std.
0	121.9	9.1	H	H-1	0.12	Std.
0	121.9	12.2	V	H-1	0.12	Std.
0	121.9	12.2	H	H-1	0.12	Std.
0	182.9	0.5	V	H-1	0.34	Std.
0	182.9	0.5	H	H-1	0.13	Std.
0	182.9	1.8	V	H-1	0.24	Std.

Table 2.2. Pre-DICE THROW II, Event 1 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)*	Gage Set Range (mps)	Canister Type
120	121.9	6.1	H	H-1	0.12	Std.
120	121.9	6.1	H	H-1	0.12	Std.
180	33.5	0.5	V	L-1	3.0	Std.
180	33.5	0.5	H	L-1	1.8	Std.
240	24.4	0.5	V	L-1	5.5	Std.
240	24.4	0.5	H	L-1	3.5	Std.
240	24.4	1.8	V	L-1	3.7	Std.
240	24.4	1.8	H	L-1	3.5	Std.
240	33.5	0.5	V	L-1	3.0	Std.
240	33.5	0.5	H	L-1	1.8	Std.
240	33.5	1.8	V	L-1	2.1	Std.
240	33.5	1.8	H	L-1	1.8	Std.
240	48.8	0.5	V	H-1	1.5	Std.
240	48.8	0.5	H	H-1	0.82	Std.
240	48.8	1.8	V	H-1	1.1	Std.
240	48.8	1.8	H	H-1	0.82	Std.
240	48.8	3.7	V	H-1	0.76	Std.
240	48.8	3.7	H	H-1	0.82	Std.
240	70.1	0.5	V	H-1	0.76	Std.
240	70.1	0.5	H	H-1	0.43	Std.
240	70.1	3.7	V	H-1	0.40	Std.
240	70.1	3.7	H	H-1	0.43	Std.
240	121.9	0.5	V	H-1	0.40	Std.
240	121.9	0.5	H	H-1	0.18	Std.
240	121.9	1.8	V	H-1	0.30	Std.
240	121.9	1.8	H	H-1	0.14	Std.

Table 2.2. Pre-DICE THROW II, Event 1 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
0	182.9	1.8	H	H-1	0.10	Std.
0	182.9	3.7	V	H-1	0.18	Std.
0	182.9	3.7	H	H-1	0.07	Std.
60	33.5	0.5	V	L-1	3.0	Std.
60	33.5	0.5	H	L-1	1.8	Std.
120	24.4	0.5	V	L-1	5.5	Std.
120	24.4	0.5	H	L-1	3.5	Std.
120	24.4	1.8	V	L-1	3.7	Std.
120	24.4	1.8	H	L-1	3.5	Std.
120	33.5	0.5	V	L-1	3.0	Std.
120	33.5	0.5	H	L-1	1.8	Std.
120	33.5	1.8	V	L-1	2.1	Std.
120	33.5	1.8	H	L-1	1.8	Std.
120	48.8	0.5	V	H-1	1.5	Std.
120	48.8	0.5	H	H-1	0.82	Std.
120	48.8	1.8	V	H-1	1.1	Std.
120	48.8	1.8	H	H-1	0.82	Std.
120	48.8	3.7	V	H-1	0.76	Std.
120	48.8	3.7	H	H-1	0.82	Std.
120	70.1	0.5	V	H-1	0.76	Std.
120	70.1	0.5	H	H-1	0.43	Std.
120	70.1	3.7	V	H-1	0.40	Std.
120	70.1	3.7	H	H-1	0.43	Std.
120	121.9	0.5	V	H-1	0.40	Std.
120	121.9	0.5	H	H-1	0.18	Std.
120	121.9	1.8	V	H-1	0.30	Std.
120	121.9	1.8	H	H-1	0.14	Std.

Table 2.2. Pre-DICE THROW II, Event 1 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
240	121.9	6.1	V	H-1	0.15	Std.
240	121.9	6.1	H	H-1	0.12	Std.
300	33.5	0.5	V	L-1	3.0	Std.
300	33.5	0.5	H	L-1	1.8	Std.

* H - Horizontal
V - Vertical
T - Transverse

** H - High Sensitivity
L - Low Sensitivity
-1 - 1000 cs damping fluid

Table 2.3. Pre-DICE THROW II, Event 2

ACCELEROMETER IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Gage Model**	Gage Range (g)	Set Range (g)	Canister Type
0	12.2	0.5	V	2264	30 kg	10 kg	Micro
0	12.2	0.5	H	2264	20 kg	5.5 kg	Micro
0	12.2	1.8	V	2264	30 kg	10 kg	Micro
0	12.2	1.8	H	2264	20 kg	5.5 kg	Micro
0	18.3	0.5	V	2264	5 kg	2.3 kg	Micro
0	18.3	0.5	H	2264	5 kg	1.3 kg	Micro
0	18.3	1.8	V	2264	5 kg	2 kg	Micro
0	18.3	1.8	H	2264	5 kg	1.1 kg	Micro
0	18.3	3.7	V	2261M6	10 kg	2 kg	Mini
0	18.3	3.7	H	2261M6	10 kg	1.1 kg	Mini
0	18.3	6.1	V	2261M6	10 kg	2 kg	Mini
0	18.3	6.1	H	2261M6	10 kg	1.1 kg	Mini
0	18.3	9.1	V	2261M6	10 kg	2 kg	Mini
0	18.3	9.1	H	2261M6	10 kg	1.1 kg	Mini
0	24.4	3.7	V	2261C	2.5 kg	700 g	Mini
0	24.4	3.7	H	2261C	2.5 kg	400 g	Mini
0	24.4	6.1	V	2261C	2.6 kg	700 g	Mini
0	24.4	6.1	H	2261C	2.5 kg	400 g	Mini
0	24.4	9.1	V	2261C	2.5 kg	700 g	Mini
0	24.4	9.1	H	2261C	2.5 kg	400 g	Mini
0	33.5	3.7	V	2262C	1 kg	200 g	Mini
0	33.5	3.7	H	2262C	200 g	150 g	Mini
0	33.5	6.1	V	2262C	1 kg	200 g	Mini
0	33.5	6.1	H	2262C	200 g	150 g	Mini
120	33.5	3.7	V	2262C	1 kg	200 g	Mini
120	33.5	3.7	H	2262C	200 g	150 g	Mini
120	33.5	6.1	V	2262C	1 kg	200 g	Mini

Table 2.3. Pre-DICE THROW II, Event 2 (Continued)

ACCELEROMETER IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Gage Model**	Gage Range (g)	Set Range (g)	Canister Type
120	33.5	6.1	H	2262C	200 g	150 g	Mini
240	33.5	3.7	V	2262C	1 kg	200 g	Mini
240	33.5	3.7	H	2262C	200 g	150 g	Mini
240	33.5	6.1	V	2262C	1 kg	200 g	Mini
240	33.5	6.1	H	2262C	200 g	150 g	Mini

* H - Horizontal
V - Vertical
** Manufactured by Endevco

Table 2.4. Pre-DICE THROW II, Event 2

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
0	24.4	0.5	V	L-1	5.5	Std.
0	24.4	0.5	H	L-1	3.5	Std.
0	24.4	1.8	V	L-1	3.7	Std.
0	24.4	1.8	H	L-1	3.5	Std.
0	33.5	0.5	V	L-1	3.0	Std.
0	33.5	0.5	H	L-1	1.8	Std.
0	33.5	1.8	V	L-1	2.1	Std.
0	33.5	1.8	H	L-1	1.8	Std.
0	33.5	9.1	V	H-1	0.55	Std.
0	33.5	9.1	H	H-1	1.1	Std.
0	39.6	0.5	V	L-1	4.3	Std.
0	39.6	0.5	H	L-1	2.1	Std.
0	48.8	0.5	V	H-1	1.5	Std.
0	48.8	0.5	H	H-1	0.82	Std.
0	48.8	1.8	V	H-1	1.1	Std.
0	48.8	1.8	H	H-1	0.82	Std.
0	48.8	3.7	V	H-1	0.76	Std.
0	48.8	3.7	H	H-1	0.82	Std.
0	48.8	6.1	V	H-1	0.49	Std.
0	48.8	6.1	H	H-1	0.82	Std.
0	48.8	9.1	V	H-1	0.30	Std.
0	48.8	9.1	H	H-1	0.82	Std.
0	57.9	0.5	V	L-1	3.4	Std.
0	57.9	0.5	H	H-1	0.91	Std.
0	70.1	0.5	V	H-1	0.76	Std.
0	70.1	0.5	H	H-1	0.43	Std.
0	70.1	1.8	V	H-1	0.55	Std.
0	70.1	1.8	H	H-1	0.43	Std.

Table 2.4. Pre-DICE THROW II, Event 2 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
0	70.1	3.7	V	H-1	0.40	Std.
0	70.1	3.7	H	H-1	0.43	Std.
0	70.1	6.1	V	H-1	0.27	Std.
0	70.1	6.1	H	H-1	0.43	Std.
0	85.3	0.5	V	H-1	1.1	Std.
0	85.3	0.5	H	H-1	0.30	Std.
0	91.4	0.5	V	H-1	0.91	Std.
0	91.4	0.5	H	H-1	0.21	Std.
0	97.5	0.5	V	H-1	0.67	Std.
0	97.5	0.5	H	H-1	1.8	Std.
0	106.7	0.5	V	H-1	0.55	Std.
0	106.7	0.5	H	H-1	0.15	Std.
0	121.9	0.5	V	H-1	0.40	Std.
0	121.9	0.5	H	H-1	0.18	Std.
0	121.9	1.8	V	H-1	0.30	Std.
0	121.9	1.8	H	H-1	0.14	Std.
0	121.9	3.7	V	H-1	0.22	Std.
0	121.9	3.7	H	H-1	0.12	Std.
0	121.9	6.1	V	H-1	0.15	Std.
0	121.9	6.1	H	H-1	0.12	Std.
120	33.5	0.5	V	L-1	3.0	Std.
120	33.5	0.5	H	L-1	1.8	Std.
120	48.8	0.5	V	L-1	1.5	Std.
120	48.8	0.5	H	L-1	0.82	Std.
120	48.8	1.8	V	H-1	1.1	Std.
120	48.8	1.8	H	H-1	0.82	Std.
120	48.8	3.7	V	H-1	0.76	Std.

Table 2.4. Pre-DICE THROW II, Event 2 (Continued)

VELOCITY GAGE IDENTIFICATION

Radial (deg)	Range (m)	Depth (m)	Orientation Mode*	Fluid Viscosity (cs)**	Gage Set Range (mps)	Canister Type
120	48.8	3.7	H	H-1	0.82	Std.
120	70.1	0.5	V	H-1	0.76	Std.
120	70.1	0.5	H	H-1	0.43	Std.
120	70.1	3.7	V	H-1	0.40	Std.
120	70.1	3.7	H	H-1	0.43	Std.
240	33.5	0.5	V	L-1	3.0	Std.
240	33.5	0.5	H	L-1	1.8	Std.
240	48.8	0.5	V	H-1	1.5	Std.
240	48.8	0.5	H	H-1	0.82	Std.
240	48.8	1.8	V	H-1	1.1	Std.
240	48.8	1.8	H	H-1	0.82	Std.
240	48.8	3.7	V	H-1	0.76	Std.
240	48.8	3.7	H	H-1	0.82	Std.
240	70.1	0.5	V1	H-1	0.76	Std.
240	70.1	0.5	H	H-1	0.43	Std.
240	70.1	3.7	V	H-1	0.40	Std.
240	70.1	3.7	H	H-1	0.43	Std.

* H - Horizontal
V - Vertical
** H - High Sensitivity
L - Low Sensitivity
-1 - 1000 cs dumping fluid

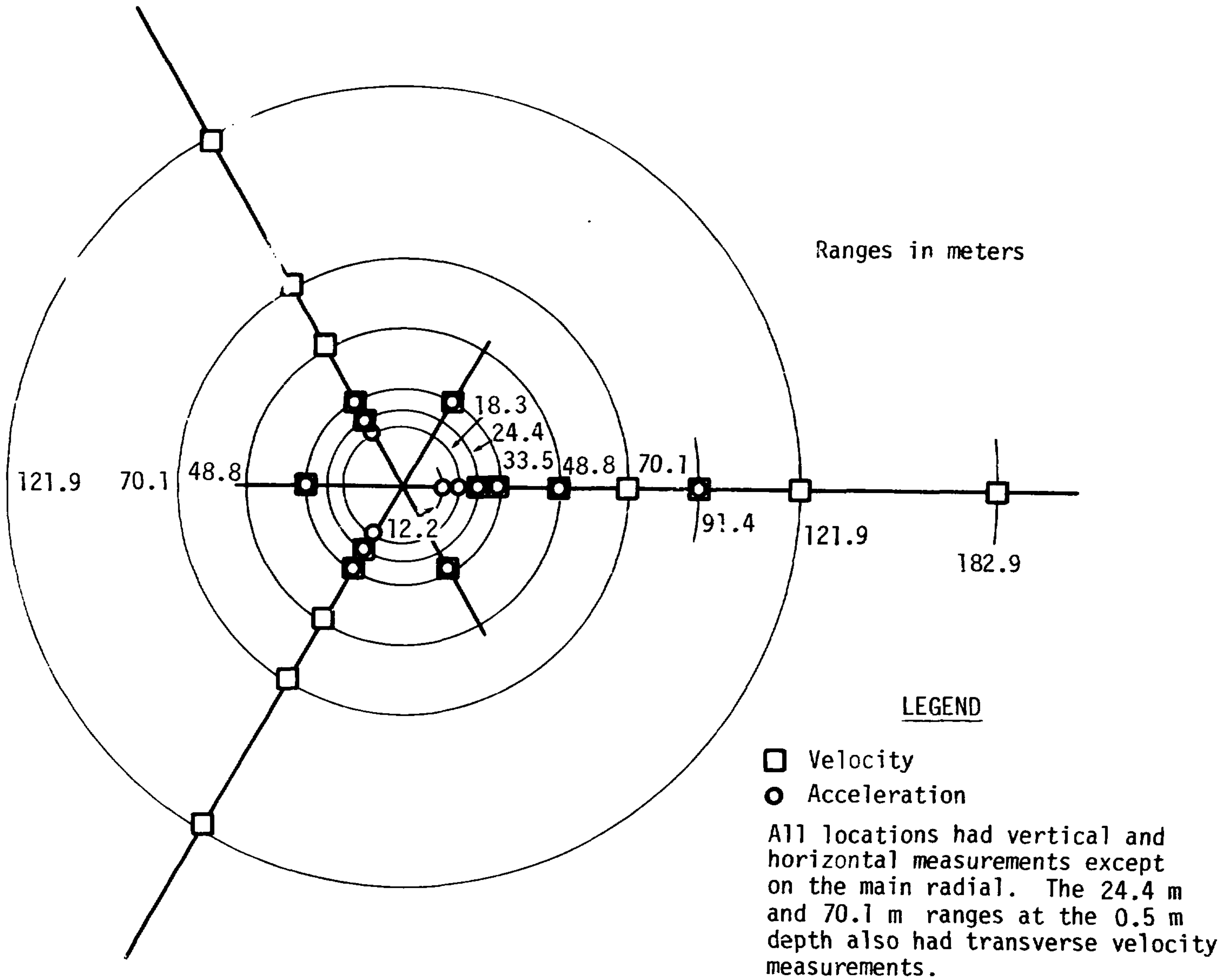


Figure 2.1. Pre-DICE THROW II, Event 1 Gage Placement Pattern Surrounding Ground Zero

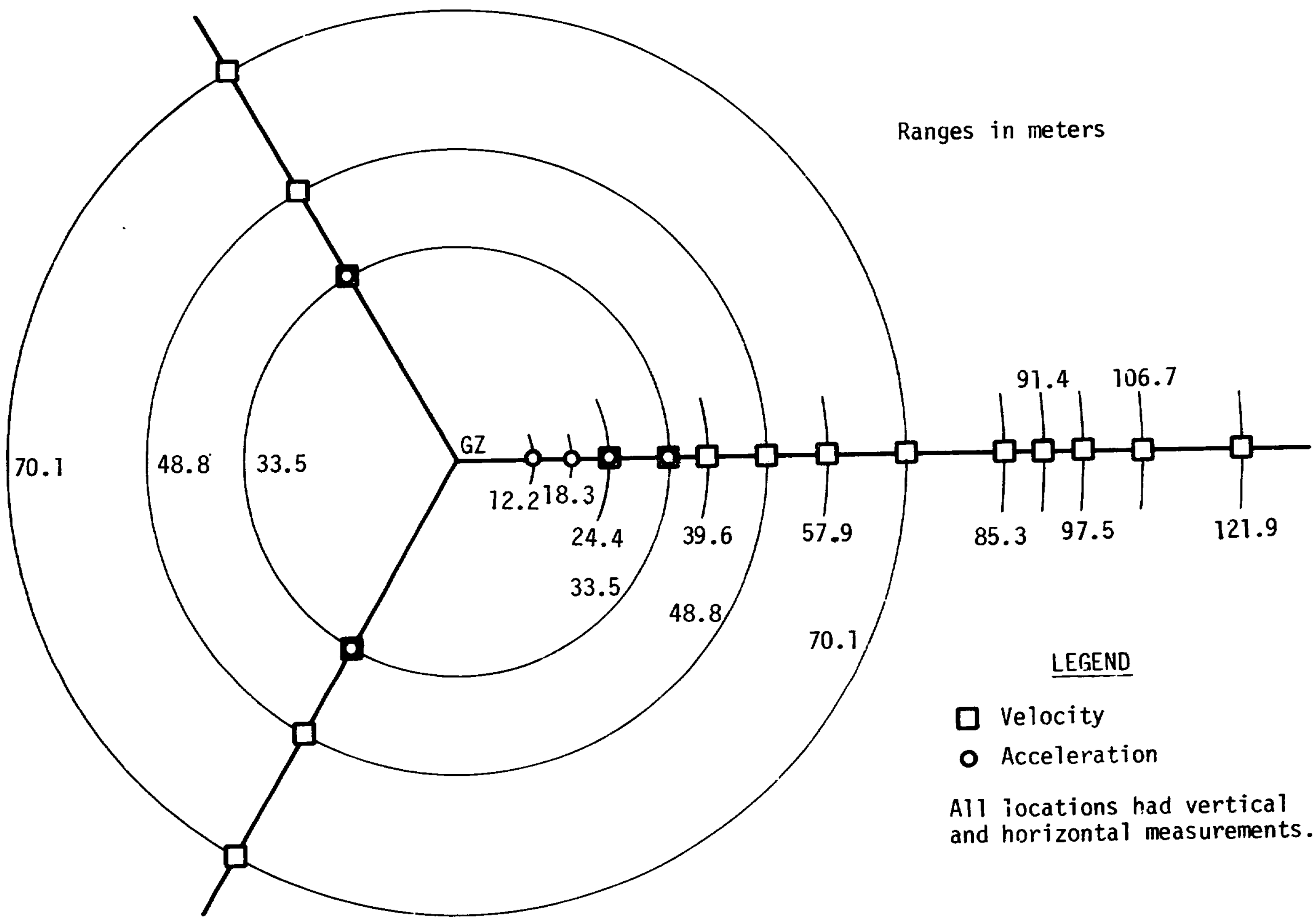


Figure 2.2. Pre-DICE THROW II, Event 2 Gage Placement Pattern Surrounding Ground Zero

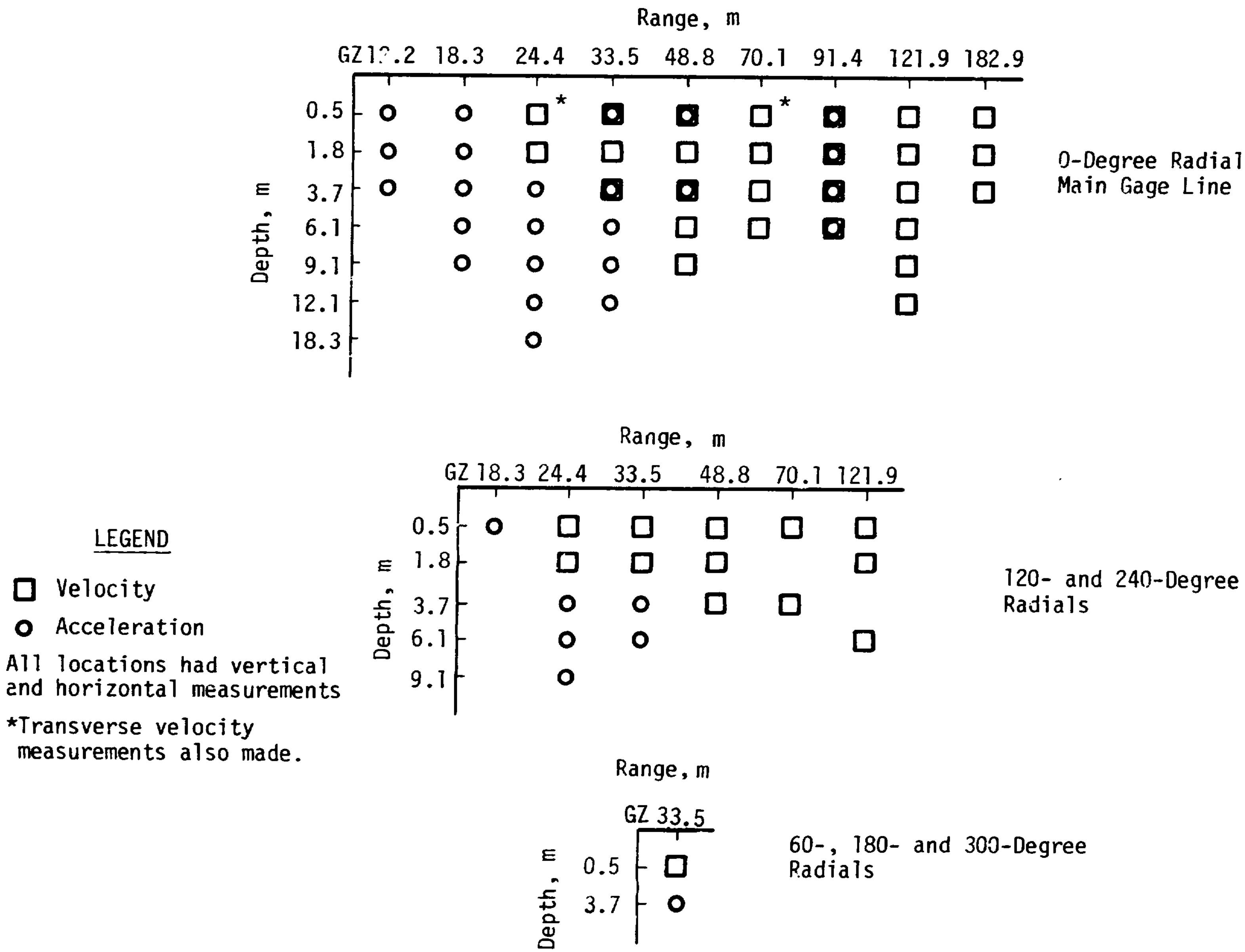


Figure 2.3. Pre-DICE THROW II, Event 1 Accelerometer and Velocity Gage Placement Profiles

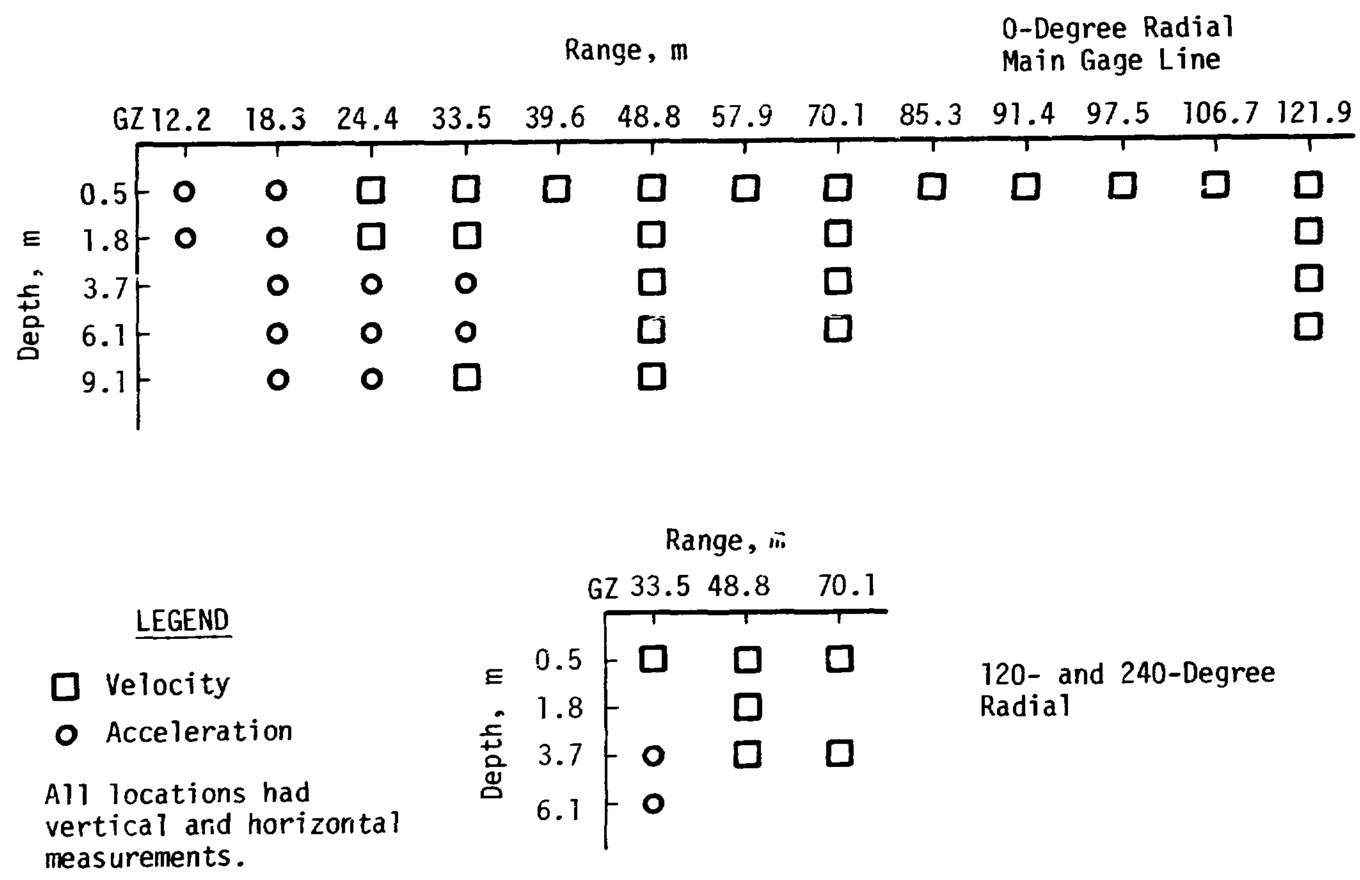
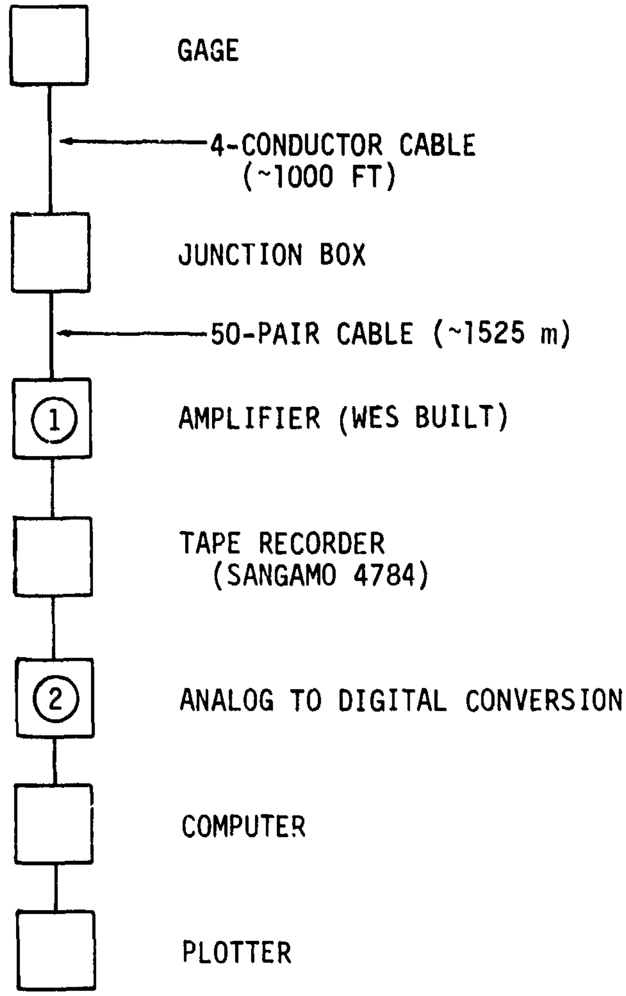


Figure 2.4. Pre-DICE THROW II, Event 2 Accelerometer and Velocity Gage Placement Profiles



(1) For Accelerometers and Stress Gages: DC op-amp system; frequency response flat to 17 kHz at max gain, greater at lesser gain.

(1) For Velocity Gages: 3 kHz carrier-amplifier-demodulator system; frequency response flat to 1 kHz.

(2) Digitization Rates: 6000 samples/sec for velocity and stress; 24,000 for acceleration.

Figure 2.5. Pre-DICE THROW II Measurement/Data Processing System

Table 2.5. List of Accelerometer Locations where Peak Data was Missing or Band Edge Data was Recorded for Pre-DICE THRCW II, Events 1 and 2

				Radials		
Range	Depth	V or H	Event #	0	120	240
12.2	3.7	V	I II	* X	X X	X X
12.2	3.7	H	I II	* X	X X	X X
18.3	3.7	V	I II	- **	X X	X X
18.3	3.7	H	I II	** -	X X	X X
18.3	6.1	V	I II	** *	X X	X X
18.3	6.1	H	I II	* **	X X	X X
18.3	9.1	V	I II	* *	X X	X X
18.3	9.1	H	I II	* *	X X	X X
24.4	3.7	V	I II	- -	* X	* X
24.4	3.7	H	I II	* -	* X	** X
24.4	6.1	V	I II	* **	* X	- X
24.4	6.1	H	I II	* -	* X	- X
24.4	9.1	V	I II	* *	- X	** X
24.4	9.1	H	I II	* **	** X	** X
24.4	12.2	V	I II	* X	X X	X X

Table 2.5. List of Accelerometer Locations where Peak Data was Missing or Band Edge Data was Recorded for Pre-DICE THROW II, Events 1 and 2 (Continued)

				Radials					
Range	Depth	V or H	Event #	0	60	120	180	240	300
33.5	3.7	V	I	**	-	**	-	*	**
			II	-	X	*	X	**	X
33.5	3.7	H	I	**	**	*	*	-	**
			II	**	X	**	X	**	X
33.5	6.1	V	I	**		**		*	
			II	-		-		**	
33.5	6.1	H	I	**		*		-	
			II	**		**		**	
48.8	3.7	H	I	**		X		X	
			II	X		X		X	

* No peak data
** Out-of-band
X No gage
\- Good data

CHAPTER 3

PREDICTION METHODS

This chapter summarizes the methods used by the Air Force Weapons Laboratory; Research and Development Associates; Field Command, Defense Nuclear Agency; and Waterways Experiment Station in predicting ground motions for the two pre-DICE THROW II events.

A. AFWL PREDICTIONS

The Air Force Weapons Laboratory (AFWL) (Reference 2) used the predicting procedures outlined in "Air Force Manual for Design and Analysis of Hardened Structures," AFWL-TR-74-102, and the results of HE test data analysis presented in "An Analysis of Outrunning Ground Motions," AFWL-TR-74-220.

The predicted crater volume was used to predict the crater induced motions. One departure from TR-74-102 was made in the displacement prediction, in that the displacement was not assumed independent of depth. The equations for near surface displacement were applied to depths less than 0.1 $V^{1/3}$, where V is predicted crater volume, but for depths greater than 0.1 $V^{1/3}$, the displacement was attenuated using fits to MIDDLE GUST data scaled to crater volume. Predictions for these direct induced motions are given in Figures 3.1 through 3.3.

The airblast induced ground shock was predicted with a simplified one-dimensional procedure recommended by TR-74-102 using a one-dimensional computer code. A bilinear model was assumed with Cp = 0.5 C_i for the soil above the water table, and Cp = 0.75 C_i for the soil below the water table (Cp = peak velocity and Ci = seismic velocity).

The oscillatory components of velocity at the 70.1-, 91.4-, and 121.9-m (230-, 300-, and 400-foot) ranges were predicted using the

[2] Letter from J. L. Bratton, DEVG, AFWL, to Major T. Stong, DNA/SPSS, "Empirical Predictions for Pre-DICE THROW II," 12 August 1975.

results of HE data analysis presented in AFWL-TR-74-220. The oscillatory components were superimposed with direct-induced and local airblast-induced components at these ranges according to predicted time phasing.

The waveforms were constructed from assumed airblast and direct-induced waveform components, which were linearly superimposed. The superposition time correlation was determined from airshock and seismic propagation velocities.

B. RDA PREDICTIONS

R and D Associates (RDA) (Reference 3) used an empirical approach based on previous test data to predict peak components (upward, downward, and outward) of velocity and displacement as functions of range and gage depth. Comparisons were made of peak motion values from available surface tangent HE events, using yield to the one-third power to scale all distances and displacements, with velocity remaining unscaled.

The previous HE tests used in predicting Pre-DICE THROW II ground motions were MIDDLE GUST calibration shots 1, 4, 5 and 7; PACE shots 1C and 1D; MIDDLE GUST II, III and IV; PRAIRIE FLAT; DIAL PACK; MIXED COMPANY III; MINE ORE; and DISTANT PLAIN 6. Data were plotted from these events and curves fitted to these data were then used to construct contour plots of peak velocity and displacement as functions of range and depth. Figures 3.4 through 3.9 are the contour plots developed in this manner. In the case of the velocity components, the fit was generally made through the middle of the data. For displacements, it was assumed that the shallow water table would significantly enhance surface displacements.

Estimates were made of the periods associated with the peak upward, downward and outward components of the velocity waveform using $P = \frac{KD}{V}$,

[3] Letter from Robert L. Post, Jr., RDA, to Captain T. Edwards, FCDNA, "Ground Motion Predictions for Pre-DICE THROW II," 11 August 1975.

where D and V are the peak displacement and velocity associated with a given component, P is the period of the velocity component and K depends on the shape of the waveform (K=2 was used as an upper bound, K=1 for a lower bound). Figure 3.10 gives the waveform predictions derived in this manner.

C. FIELD COMMAND PREDICTIONS

The FCDNA (Reference 4) predictions were made from modifications of test data recorded on the MIDDLE GUST III event, which was detonated in a geology not unlike the near surface geology for the site of the Pre-DICE THROW II events. The predictions were made with judgmental modifications to test data resulting from differences in seismic refraction data at the two sites. Consideration was also given to the differences in material compressibility at the two sites.

D. WES PREDICTIONS

Waterways Experiment Station (WES) (Reference 5) predictions were drawn from empirical evaluation of data gathered from previous experiments at various test sites. These experiments were MIDDLE GUST II, III and IV (MG II, III and IV); DISTANT PLAIN VI (DP VI) and MINERAL ROCK (MR).

WES's predictions were made for gage ranging purposes only, and a safety factor was added so that gage ranges would be adequate and the signal conditioning equipment could be set with ample band edge capability.

The vertical and horizontal accelerations were predicted using the upper bound of the peak data obtained from MG III, DP VI and MR (refer to Figures 3.11 through 3.14). The vertical acceleration at the 0.5-m (1.5-foot) depth followed the peak data curve of MG III out to the 36.6-m (120-foot) range, then followed the slope of DP VI data out to

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[4] Letter from Captain T. Edwards, FCDNA, to Major T. Stong, DNA/SPSS, "Pre-DICE THROW Predictions," 28 May 1975.

[5] Letter from J. D. Day, WES, to Major T. Stong, DNA/SPSS, "Estimates of Ground Shock for Pre-DICE THROW II Series," 20 May 1975.

304.8 m (1000 feet). At depths greater than the 0.5 m (1.5 feet), MG III data peaks were chosen out to 39.6 m (130 feet), then the slope of predicted data followed that of MR. The horizontal predictions of acceleration at the 0.5-m (1.5-foot) depth followed the MG III data out to approximately 57.9 m (190 feet), then followed the peak data obtained on the DP VI event. For depths greater than 0.5 m (1.5 feet), the MG III data peaks were chosen for the prediction.

Figures 3.15 through 3.17 depict the vertical velocity predictions for the 0.5-, 1.8- and 3.7-m (1.5-, 6- and 12-foot) depths, respectively. The shaded areas represent the data spread for the crater induced (direct induced) motions from the MG II, III and IV events. Out to a range of 91.4 m (300 feet), the point of expected outrunning motions, the airblast overpressures were expected to influence the ground motions. A ratio of about 0.04 to 0.06 m/sec per kpascal (0.02 to 0.03 ft/sec per psi), increasing with range, was used for the predictions at the 0.5-m (1.5-foot) depth. Below these depths, the predictions were attenuated to approximately 70-, 50-, and 30-percent of the near surface velocity for the 1.8-, 3.7-, and 6.1-m (6-, 12-, and 20-foot) depths, respectively. Beyond the 91.4-m (300-foot) range at all depths, the slope of the MG III and IV upper boundary was followed. The overall prediction curve follows the upper boundary of the MG data with a 20- to 30-percent safety factor.

The horizontal velocity predictions are shown in Figure 3.18. There was no attenuation with depth out to the 91.4-m (300-foot) range. Beyond this range, the velocities were attenuated with depth as shown.

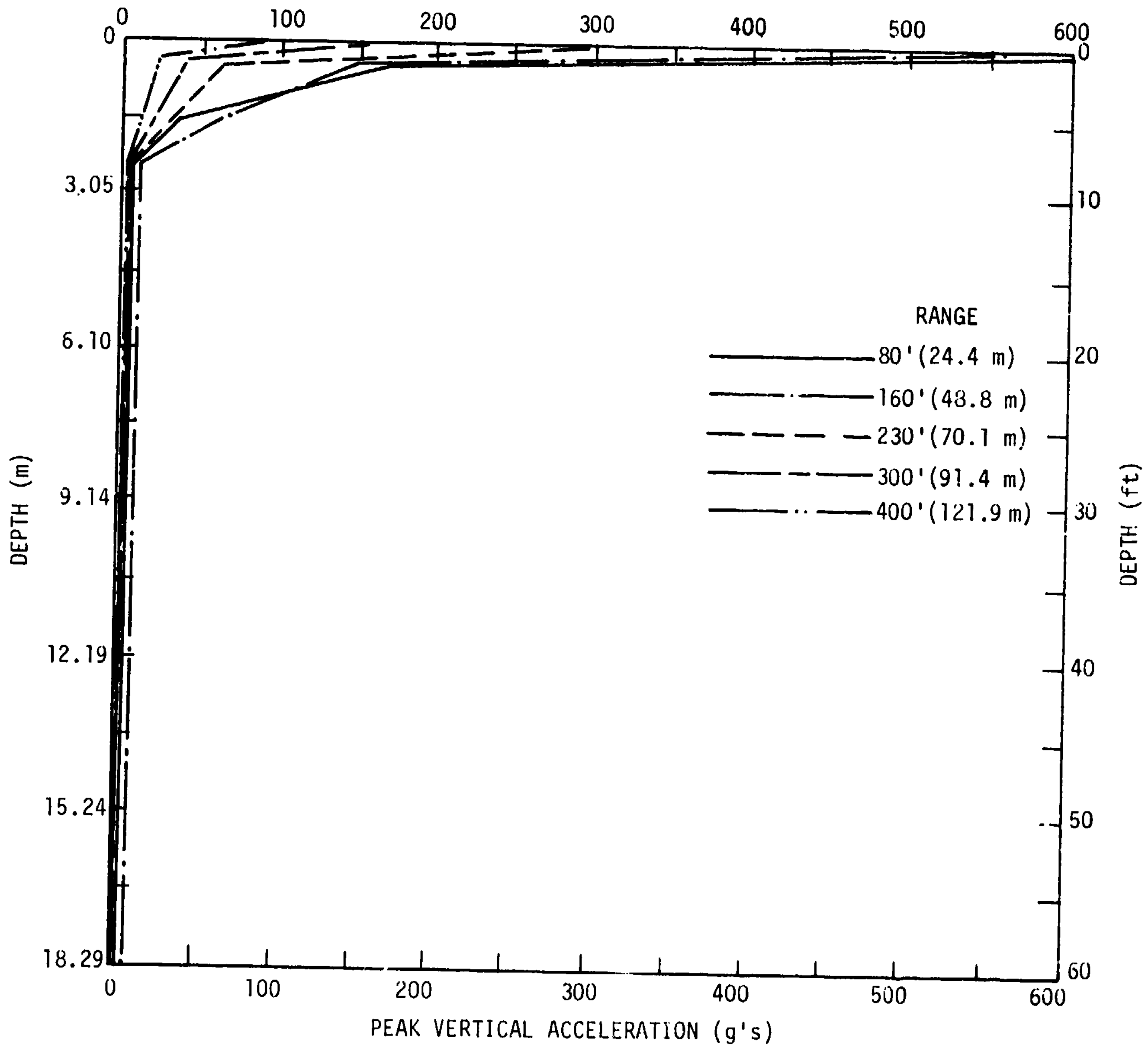


Figure 3.1. AFWL Prediction of Vertical Acceleration versus Depth for Pre-DICE THROW II.

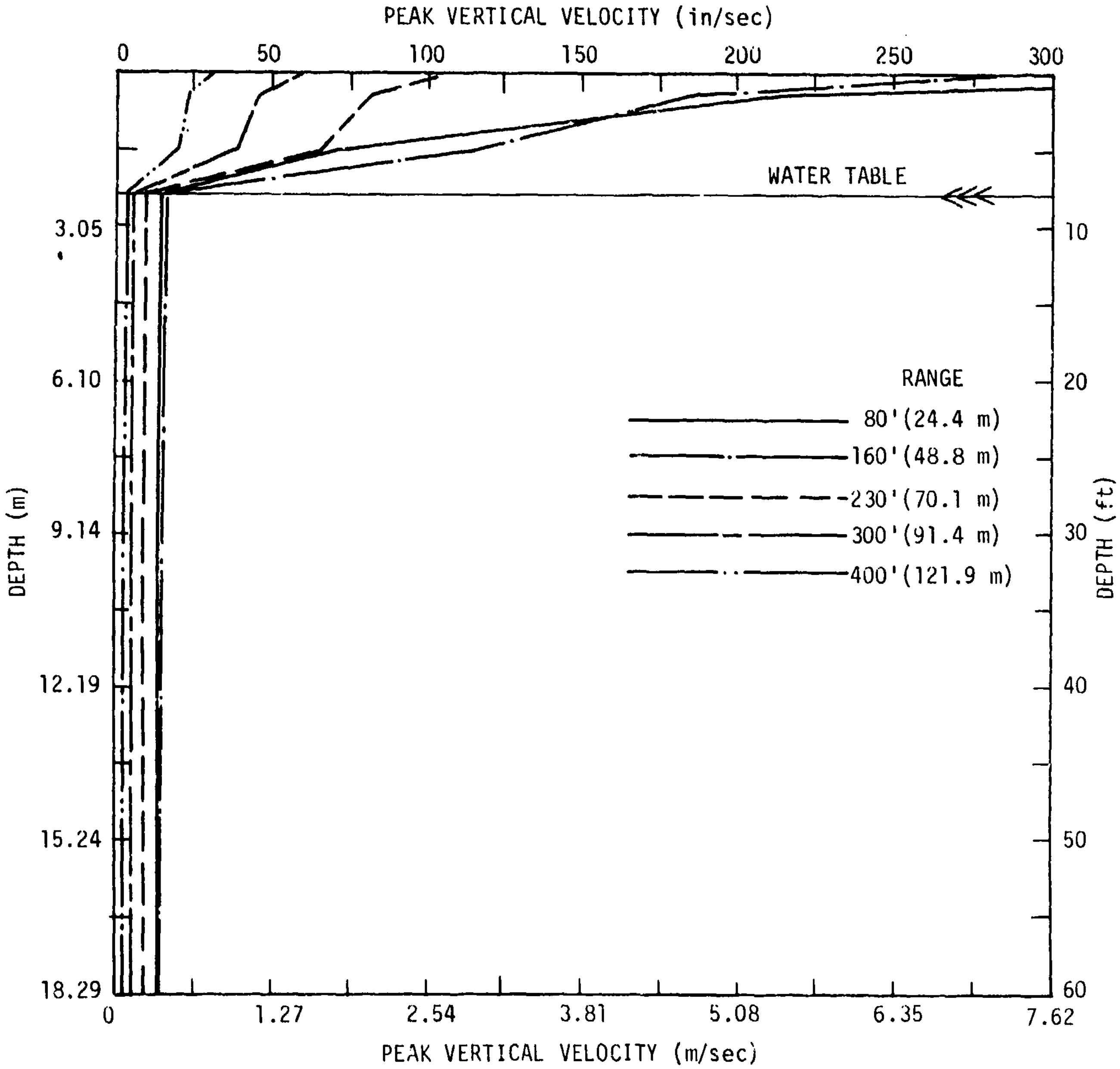


Figure 3.2. AFWL Prediction of Vertical Velocity versus Depth for Pre-DICE THROW II.

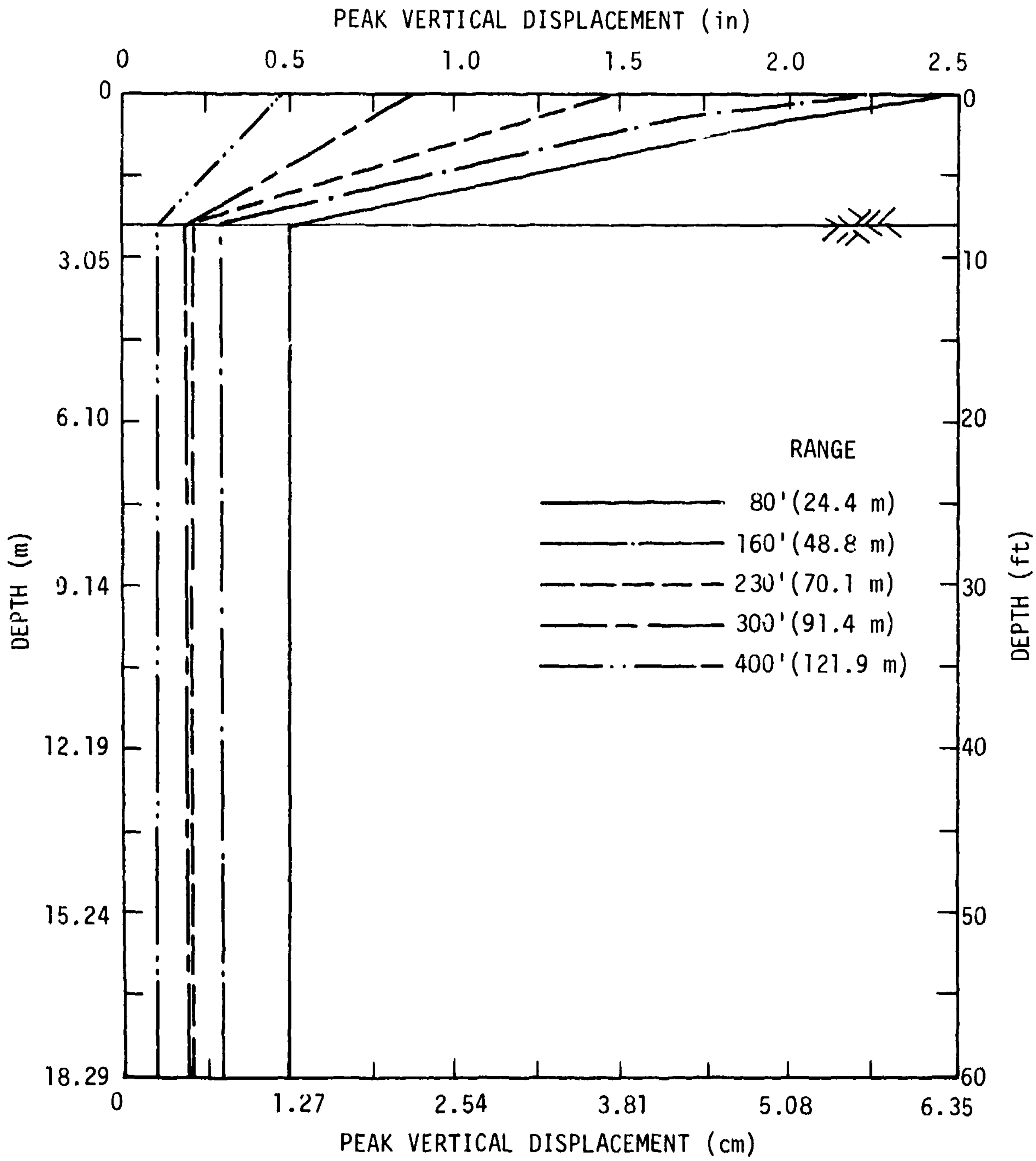


Figure 3.3. AFWL Prediction of Vertical Displacement versus Depth for Pre-DICE THROW II.

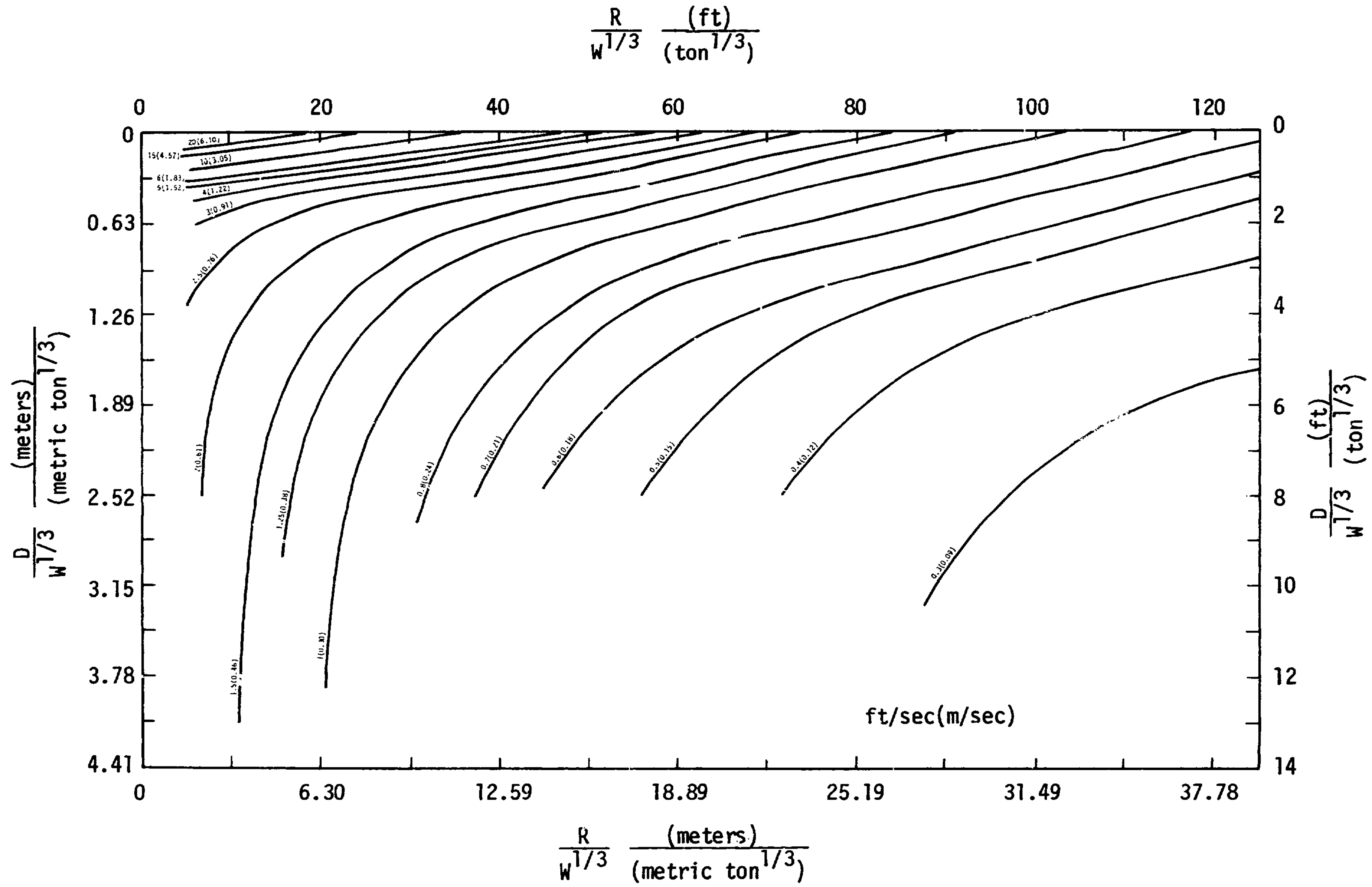


Figure 3.4. RDA Prediction of Airblast Induced Vertical Velocity for Pre-DICE THROW II

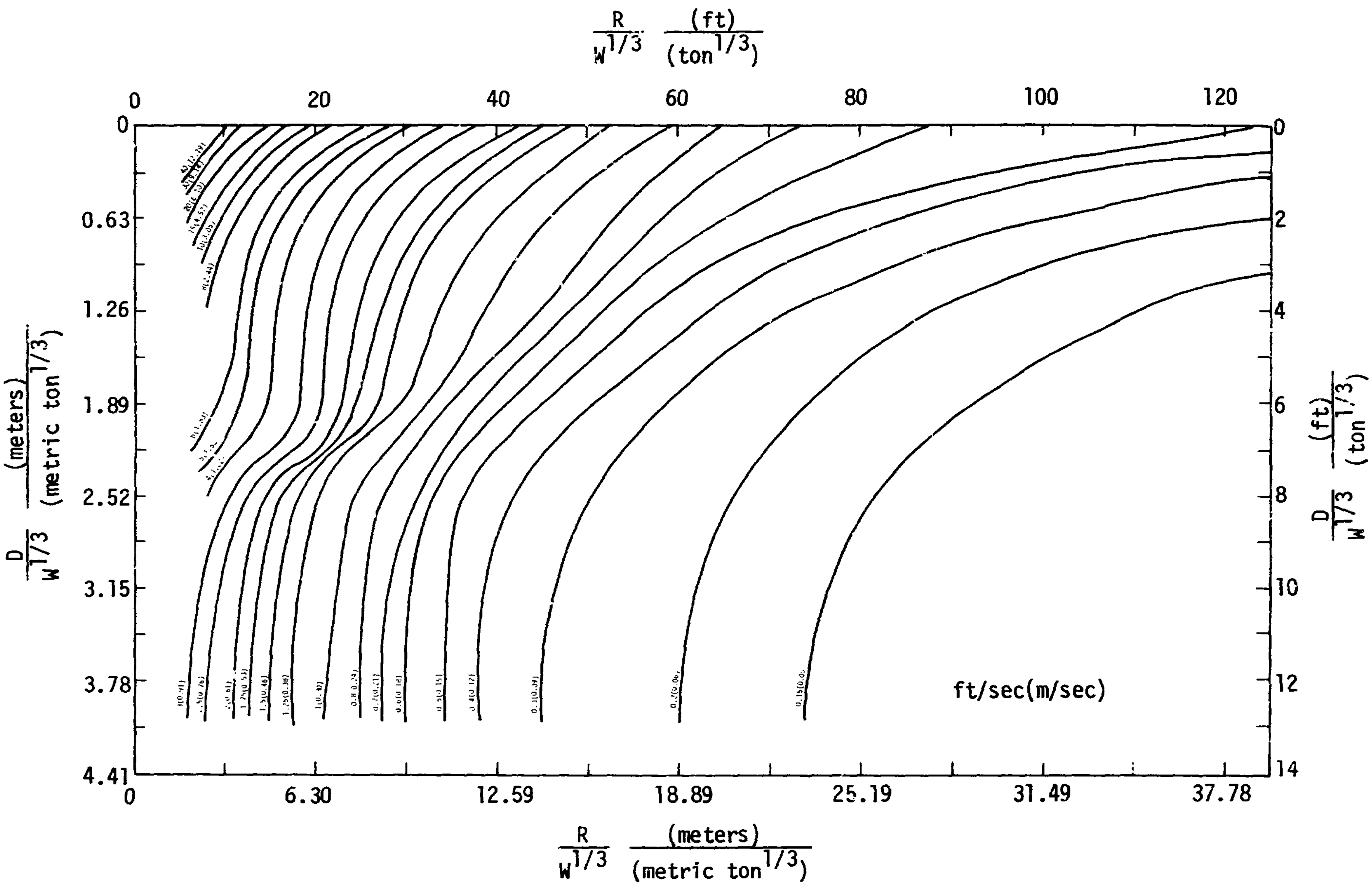


Figure 3.5. RDA Prediction of Direct Induced Vertical Velocity for Pre-DICE THROW II

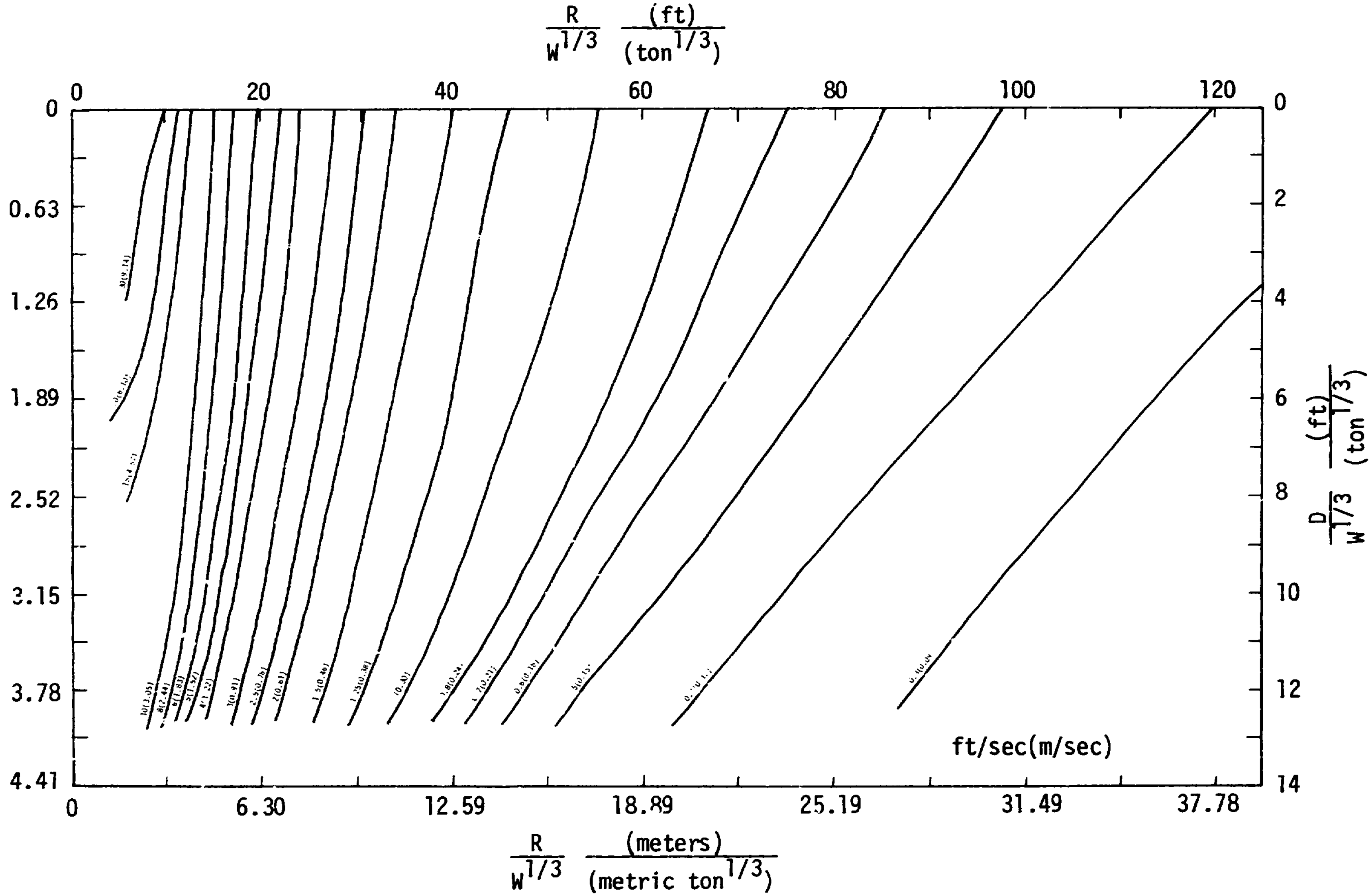


Figure 3.6. RDA Prediction of Horizontal Velocity for Pre-DICE THROW II

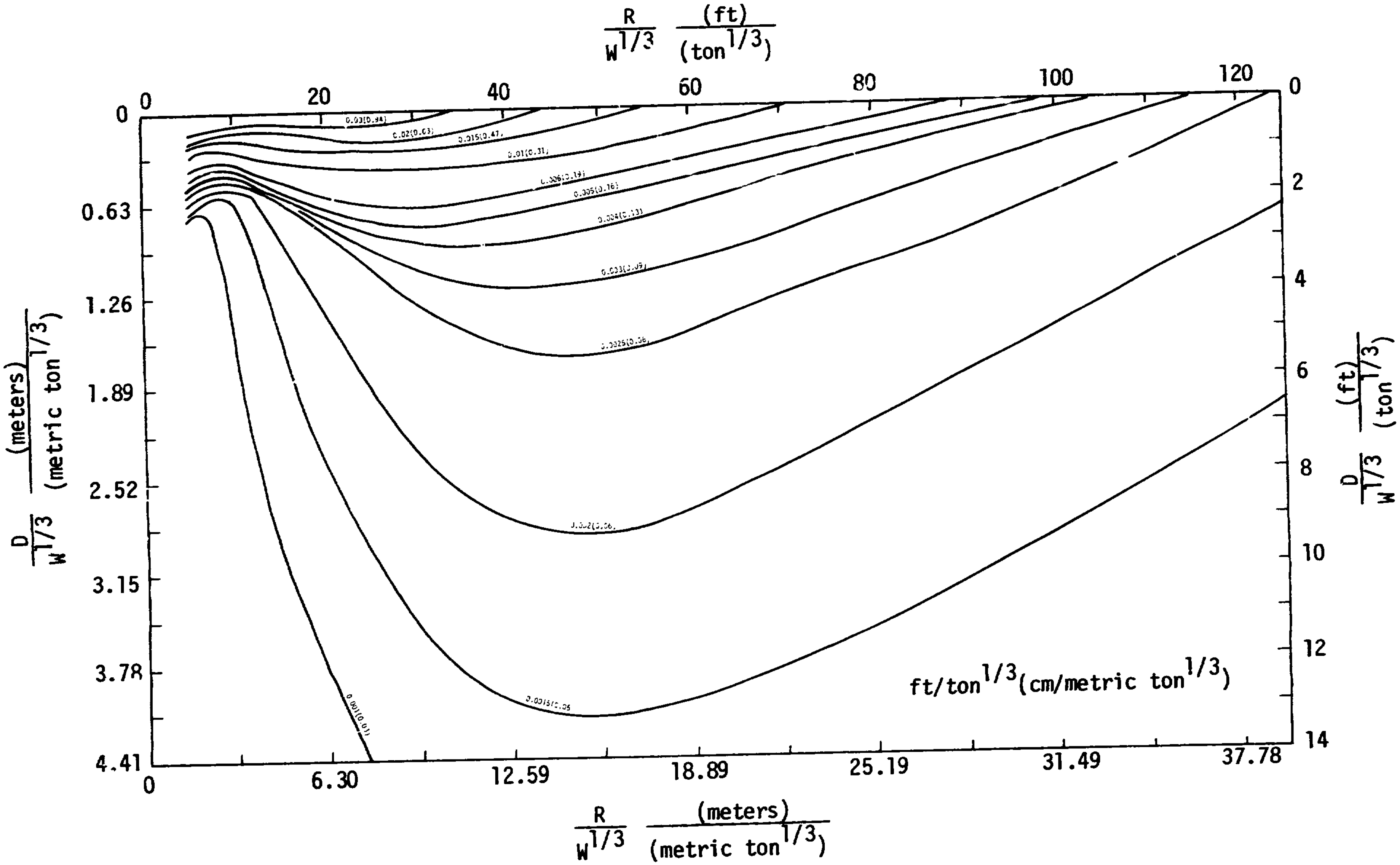


Figure 3.7. RDA Prediction of Airblast Induced Vertical Displacement for Pre-DICE THROW II

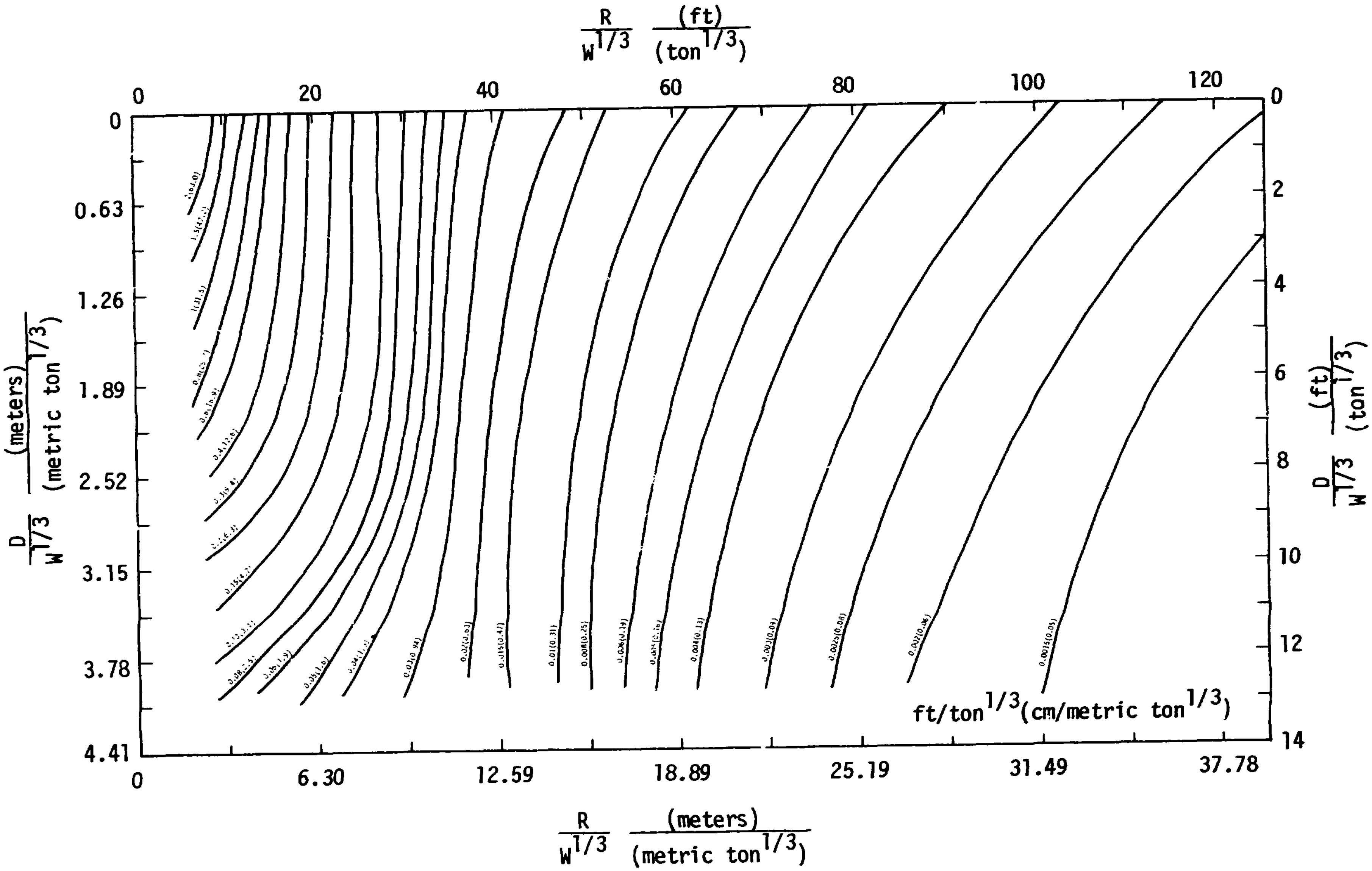


Figure 3.8. RDA Prediction of Direct Induced Vertical Displacement for Pre-DICE THROW II

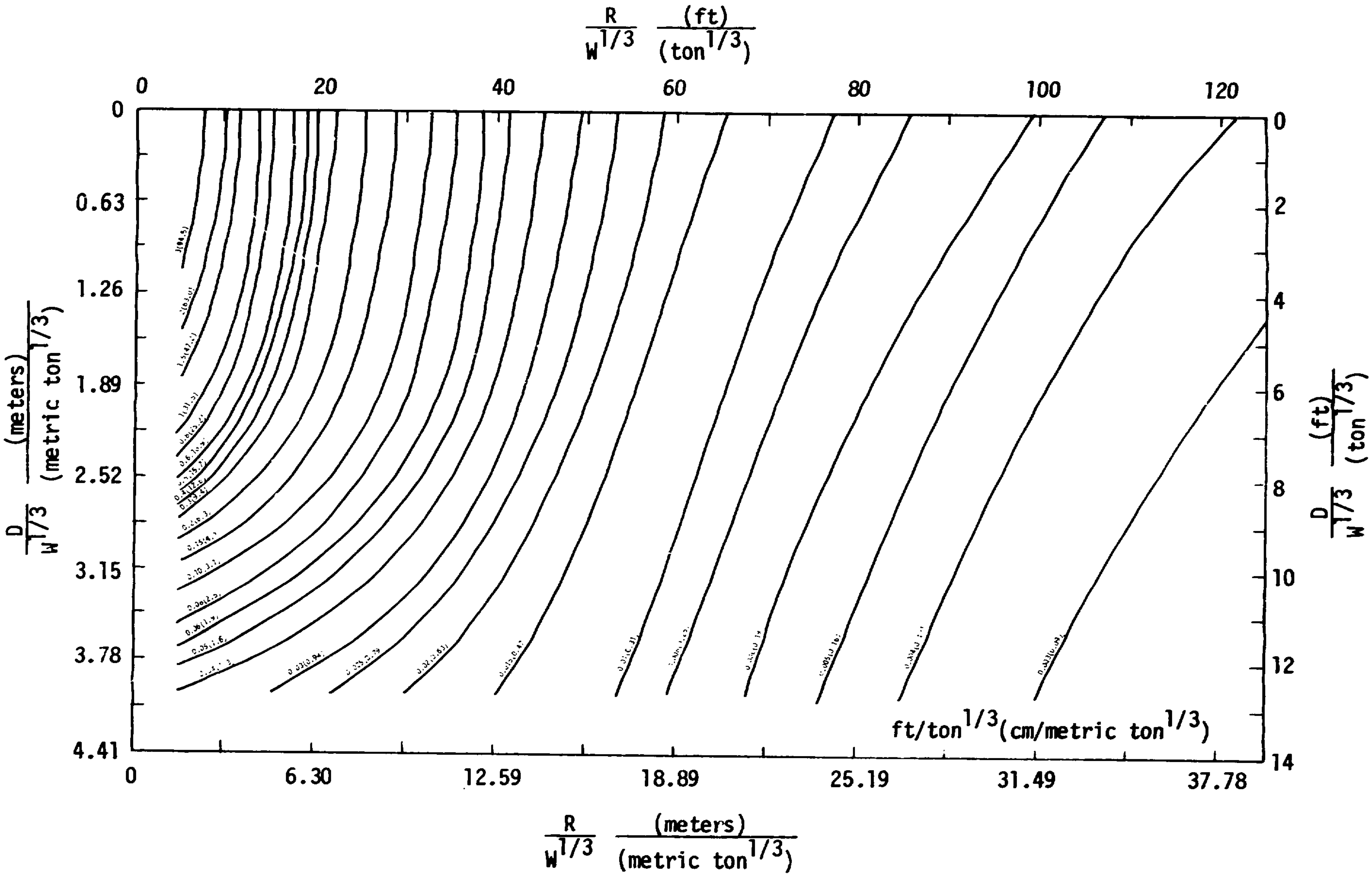


Figure 3.9. RDA Prediction of Horizontal Displacement for Pre-DICE THROW II

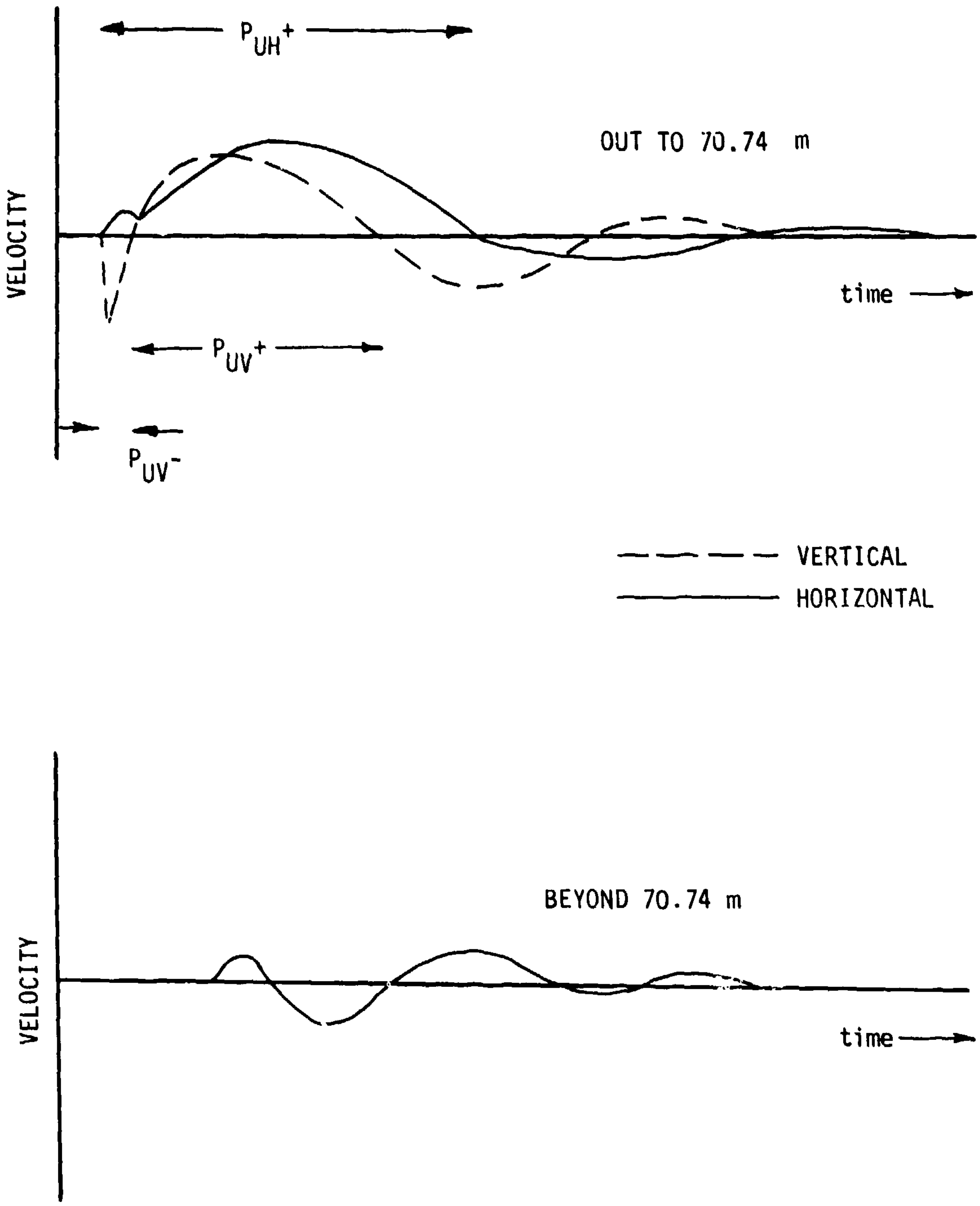


Figure 3.10. RDA's Waveform Predictions for Close-In and Beyond 70.74 Meters for Pre-DICE THROW II.

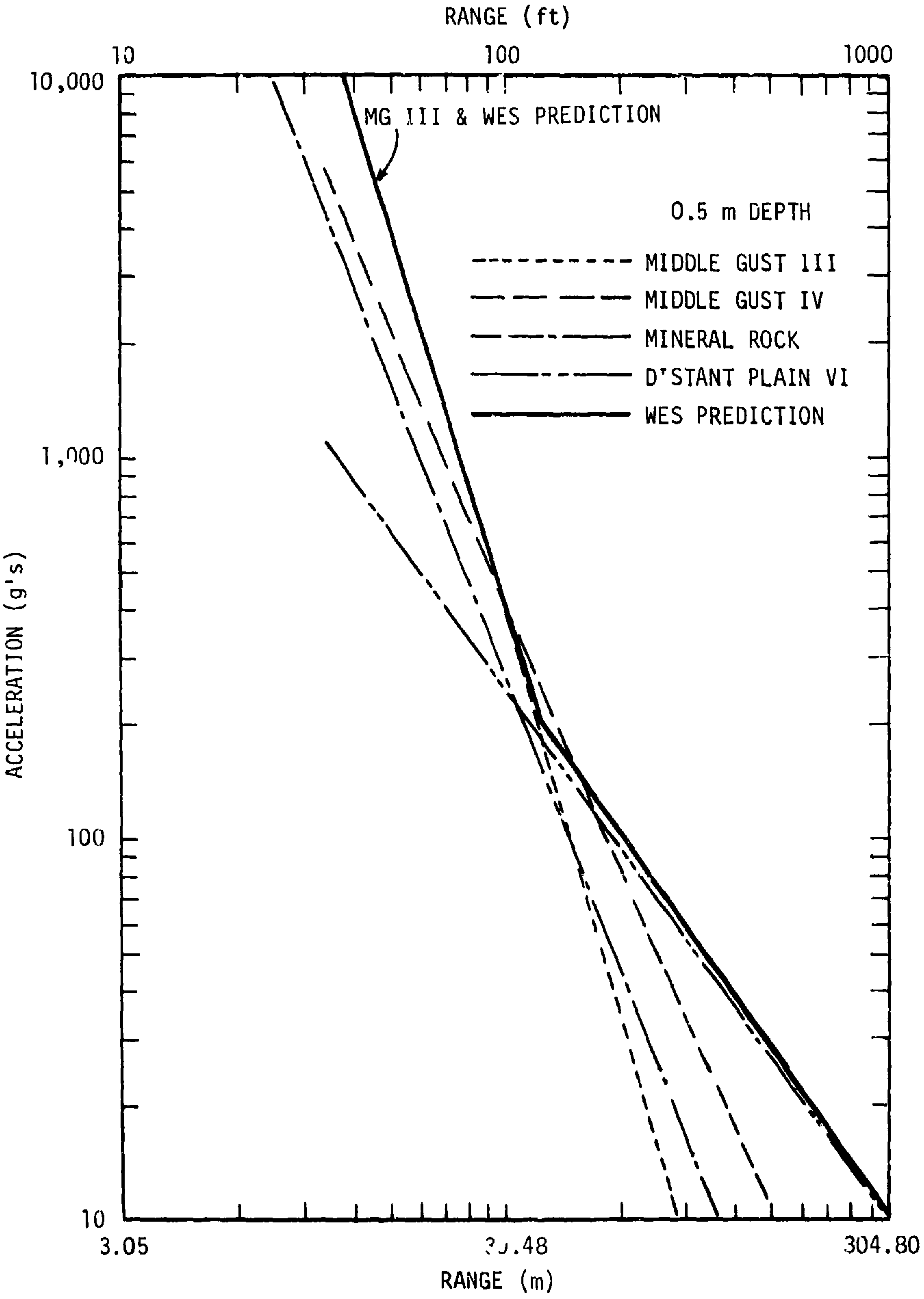


Figure 3.11. WES Prediction of Vertical Acceleration at 0.5 m Depth for Pre-DICE THROW II.

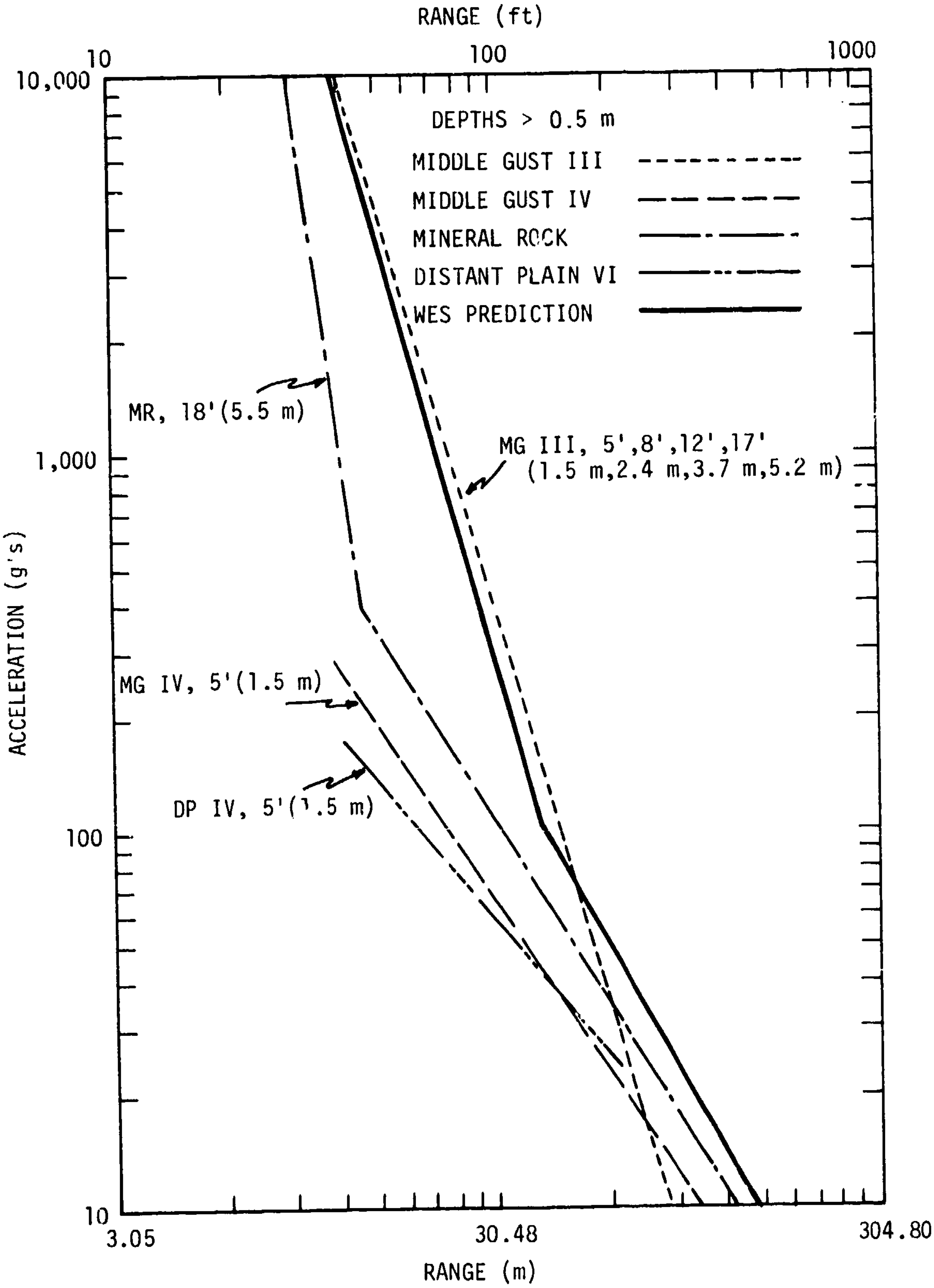


Figure 3.12. WES Prediction of Vertical Acceleration at Depths Greater than 0.5 m for Pre-DICE THROW II.

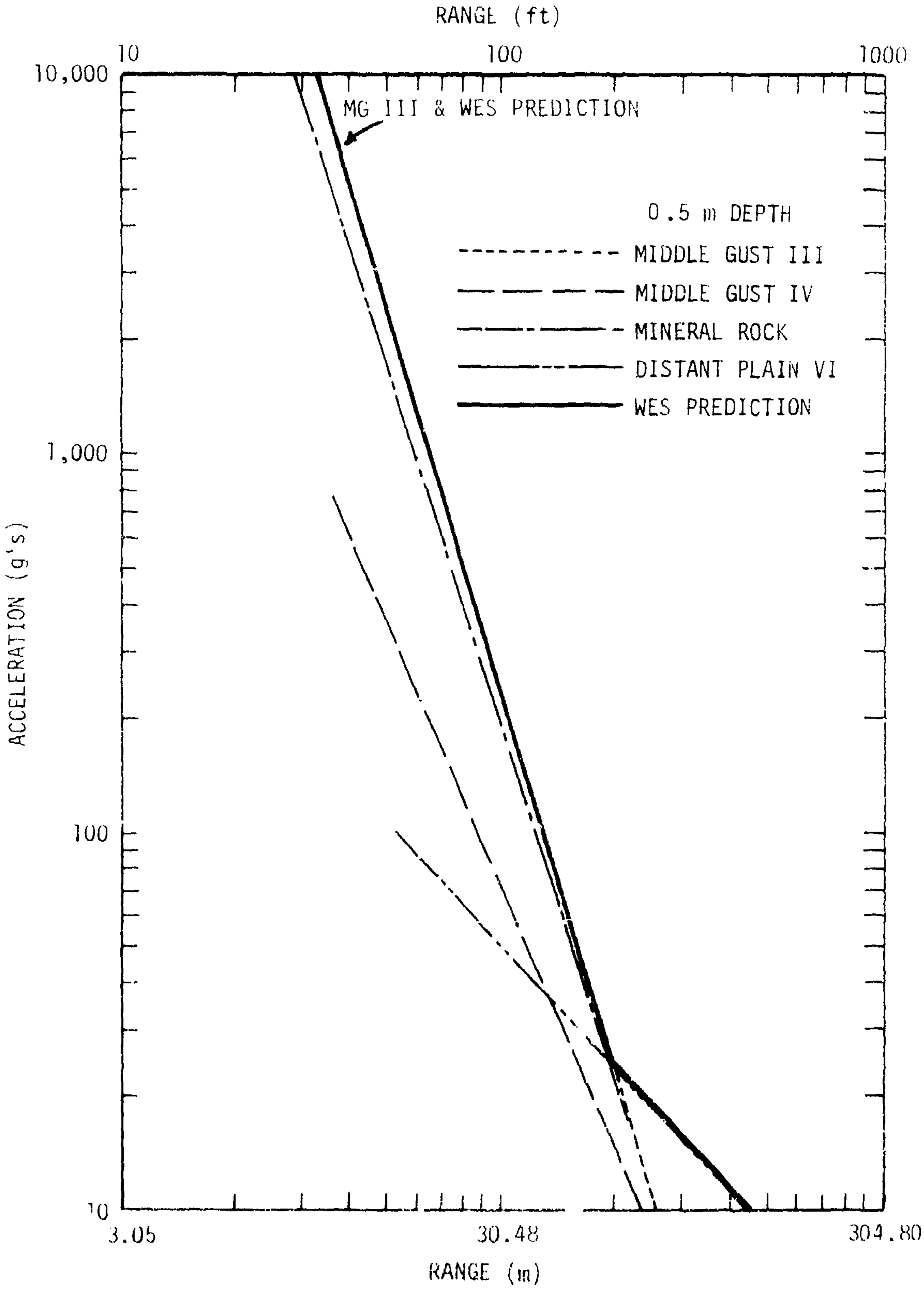


Figure 3.13. WES Prediction of Horizontal Acceleration at 0.5 m Depth for Pre-DICE THROW II.

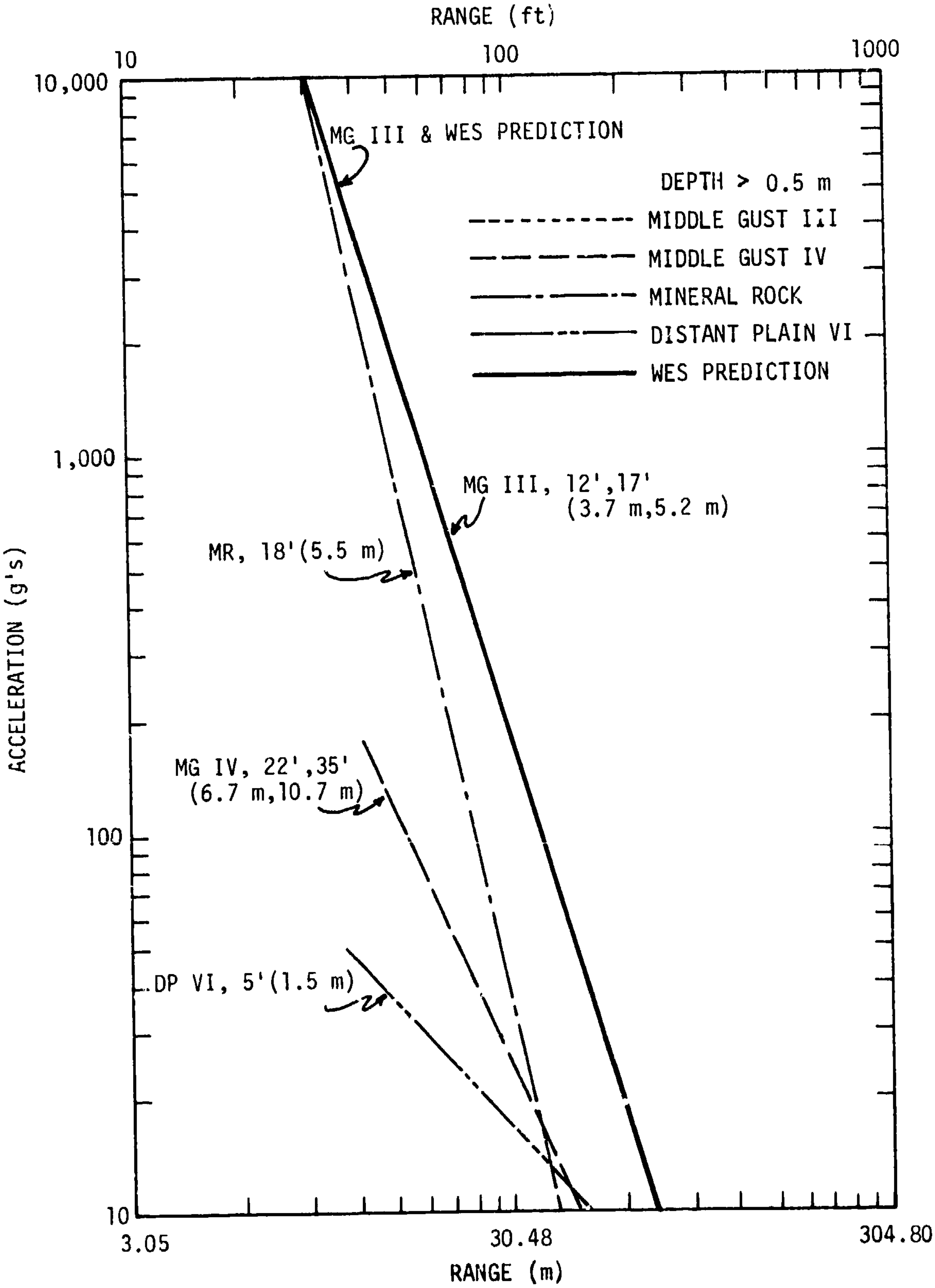


Figure 3.14. WES Prediction of Horizontal Acceleration at Depths Greater than 0.5 m for Pre-DICE THROW II.

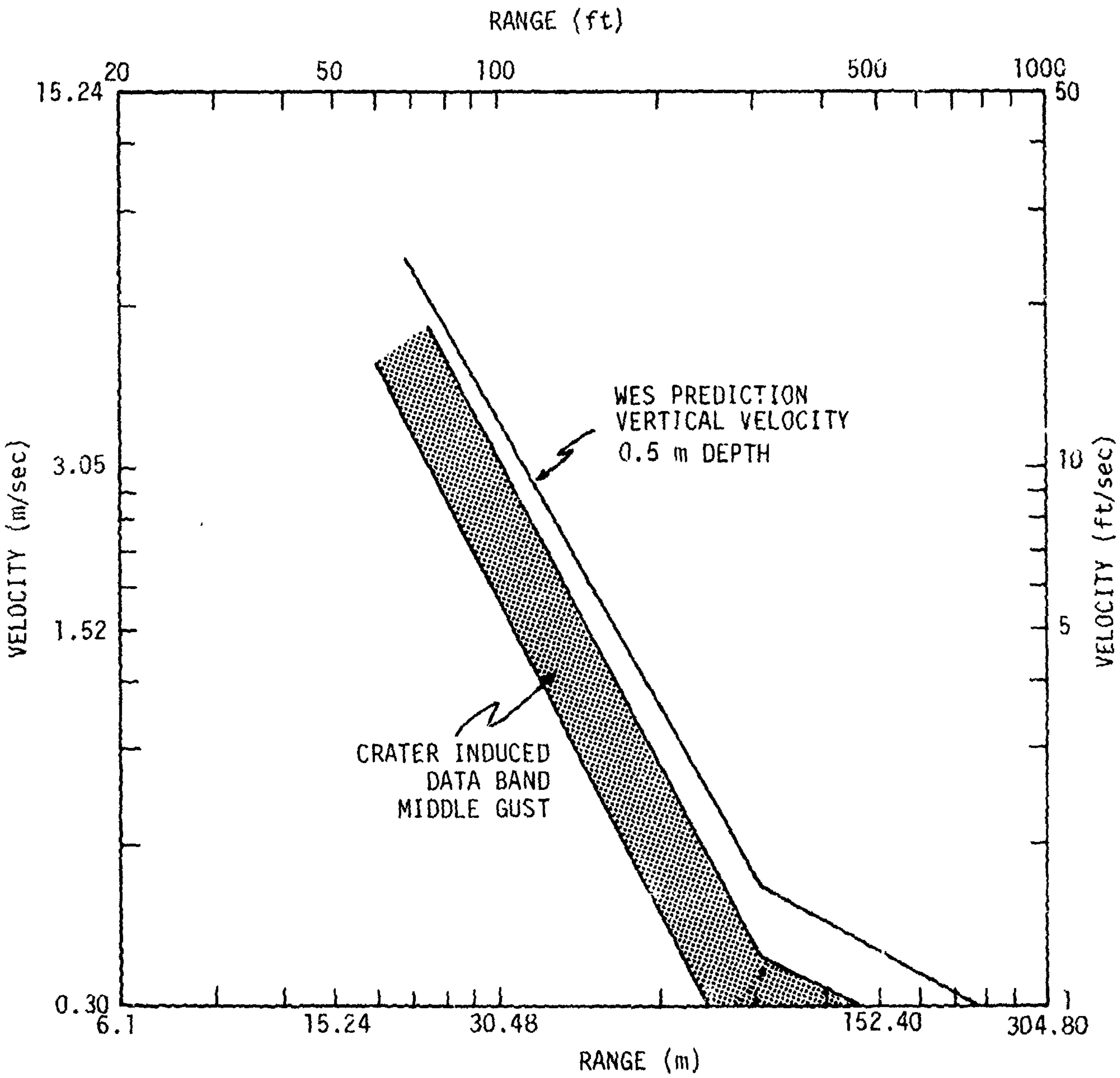


Figure 3.15. WES Prediction of Vertical Velocity at 0.5 m Depth for Pre-DICE THROW II.

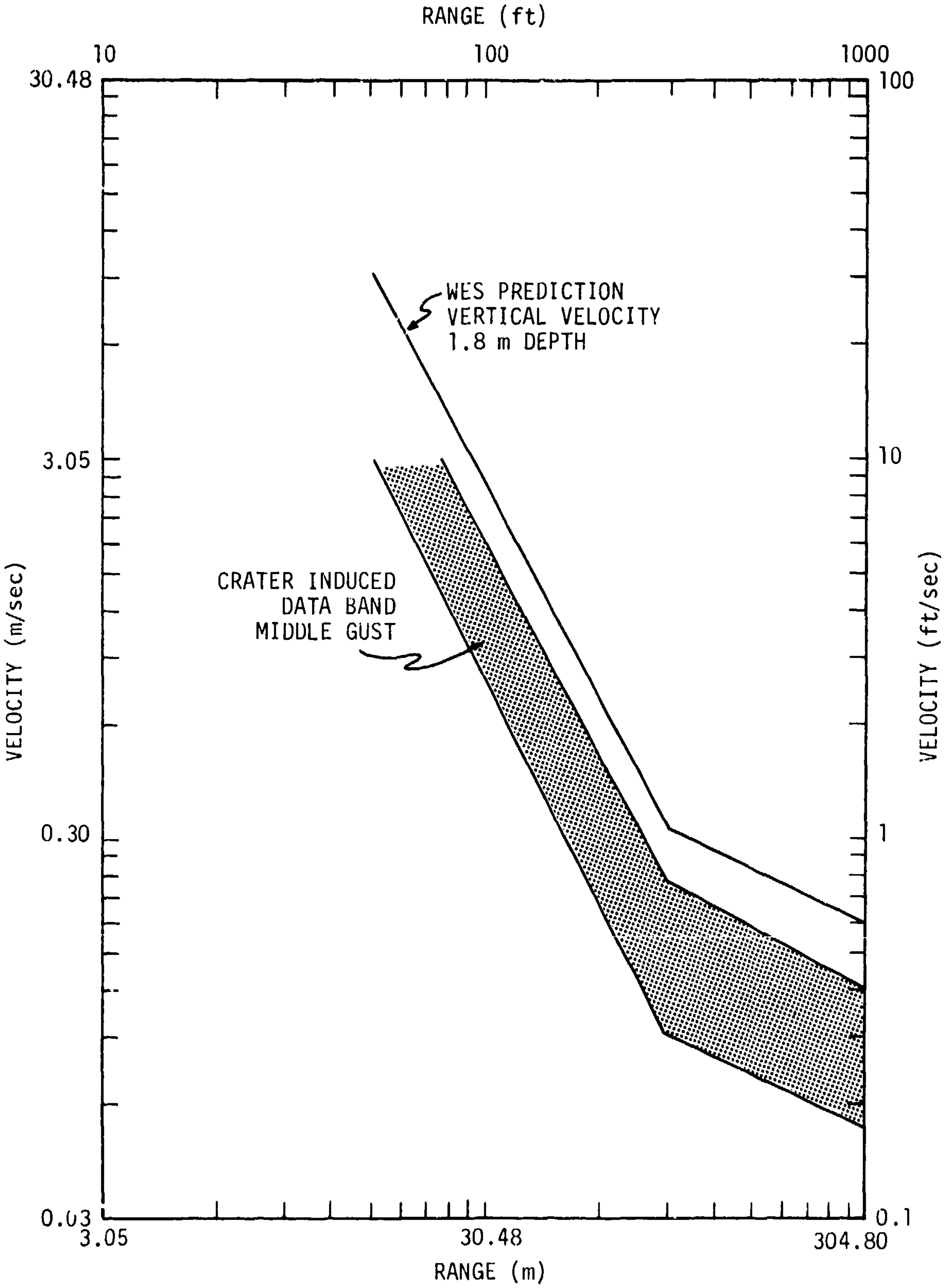


Figure 3.16. WES Prediction of Vertical Velocity at 1.8 m Depth for Pre-DICE THROW II.

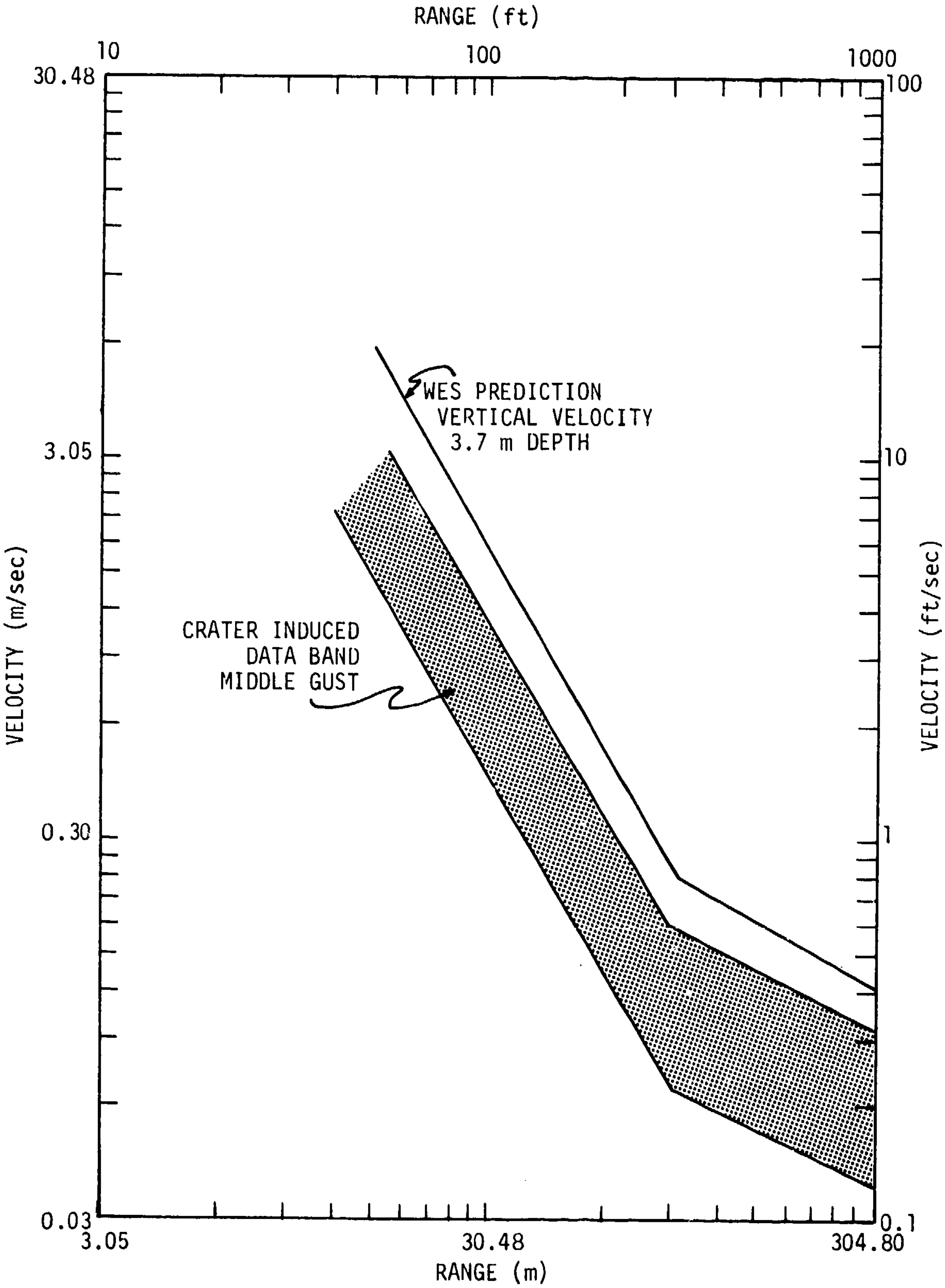


Figure 3.17. WES Prediction of Vertical Velocity at 3.7 m Depth for Pre-DICE THROW II.

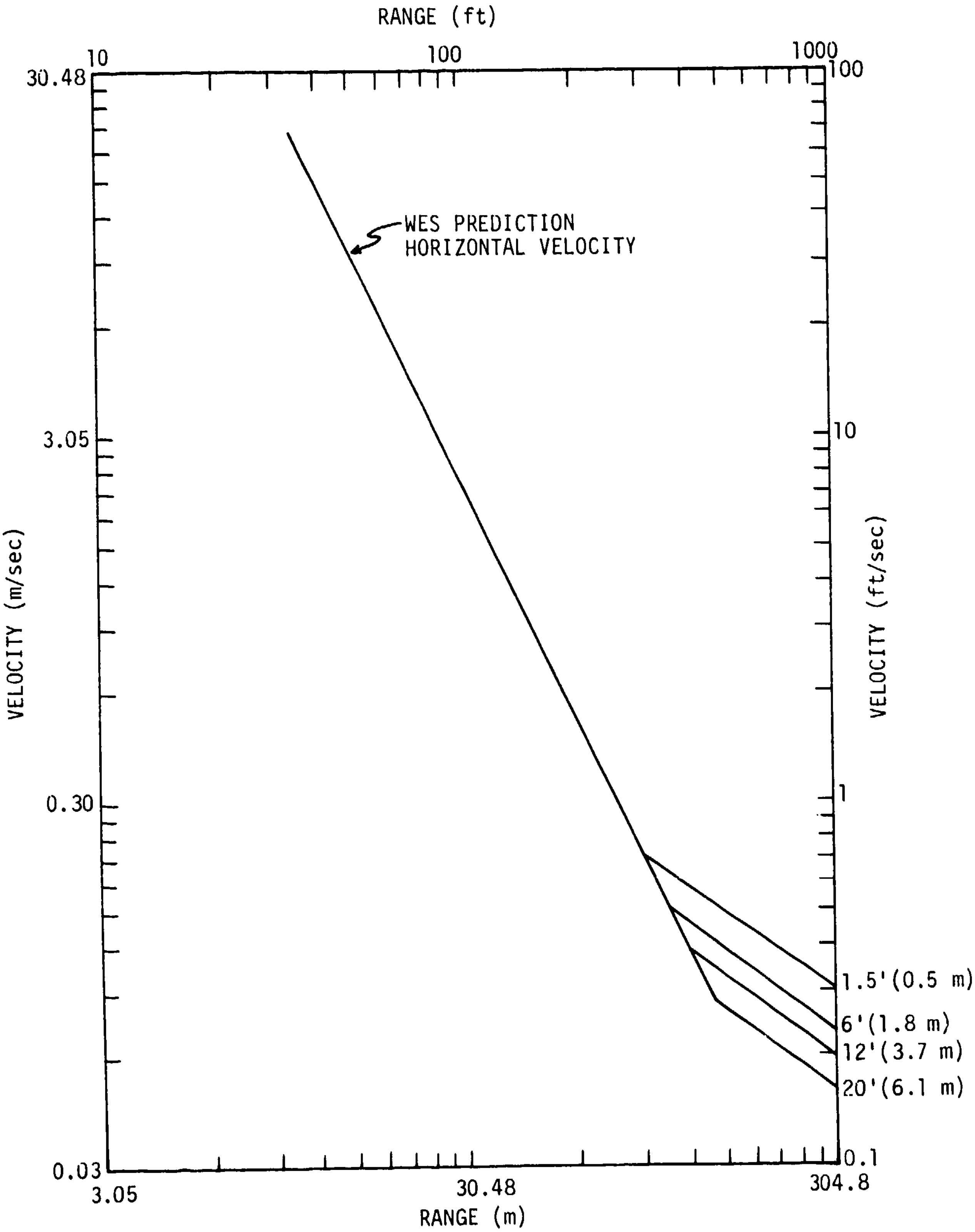


Figure 3.18. WES Prediction of Horizontal Velocity for Pre-DICE THROW II.

CHAPTER 4

COMPARISON OF DATA AND PREDICTIONS; EVENT 1

The purpose of this chapter is to compare the predictions described in Chapter 3 with the actual data obtained from Event 1. Similar comparisons for Event 2 will be made in Chapter 5. An effort has been made to present the comparisons in a way that will be as meaningful as possible. It is hoped that they will prove useful as a reference for future HE test predictions and data analysis.

A. TABULATIONS OF DATA

All of the numerical peak values used in this series of comparisons, both experimental and predicted, are given in Tables 4.1 through 4.3. Tables 4.1, 4.2, and 4.3 contain the acceleration, velocity, and displacement v[illegible], respectively, for Event 1. If more than one measurement was made at the same radial distance from ground zero and the same depth, but on a different radial, then the average value of these data is computed, and these averages are also given in the tables. Additional details pertaining to transducer type and placement are given in Chapter 2. The displacement data given in Table 4.3 are integrations of the velocity records, and are included only to indicate trends relative to the predictions.

It should be noted that, although the data columns in the tables are titled "Direct Induced (Positive)" and "Airblast Induced (negative)", these designations are correct only for the vertically oriented gages. In the case of the horizontal gages, peak positive excursions of the traces were recorded in the "Direct Induced" column, and peak negative excursions were recorded in the "Airblast Induced" column. No attempt was made to separate the two types of motions in the horizontal data, and the recorded negative peaks probably arise from elastic recovery of the medium in which the horizontal gage is situated.

In the prediction columns, the peak values predicted by each agency for direct induced (DI) or positive excursions and for airblast induced

(AI) or negative excursions are given. Where a prediction was not available at the specified location, the symbol "-" or "-/-" is used.

Deviations of the predictions from the experimental data averages were also computed. The percentage deviations were determined from the following formula:

$$\text{Percent Deviation } (\eta) = \frac{\text{Average Experimental Value - Prediction}}{\text{Average Experimental Value}} \times 100$$

A positive deviation indicates that the average data point was greater than that predicted, whereas a negative deviation indicates that it was less. It is obvious that the maximum positive percentage deviation is 100, while there is no limit to the negative deviation.

Only three types of data are included in this report, acceleration and velocity measurements and the integrated velocity data, or displacement. Some predictions of stress were made by FCDNA and AFWL, but these predictions were for ranges and depths not covered by the transducer array. Hence no attempt has been made to incorporate considerations of stress into the present study.

B. GRAPHICAL PRESENTATIONS

Following the tables, a large number of plots are given showing the experimental data and predictions in different forms. The first group of plots, Figures 4.1 through 4.6, shows the vertical acceleration data versus range from ground zero. There is a separate plot for each depth at which experimental data and predictions are available. The direct induced peaks are plotted as positive values, whereas the airblast induced peaks are plotted as negative values. Calculated percentage deviations of the predictions from the data are also plotted separately for the direct and airblast induced cases. In Figures 4.7 through 4.9, the same information is plotted as functions of depth, with a separate plot for each range.

Horizontal accelerations versus range are given in Figures 4.10 through 4.12. The same data versus depth is plotted in Figures 4.13 through 4.15. It should be noted that, in these plots as well as in others in this and the following chapter, only those data points for which a comparison between prediction and experiment was possible have been included. Predictions at locations for which no experimental data was obtained have been omitted, as have experimental points at locations for which no predictions were made. In a few cases, complete graphs have been omitted when there were no comparisons to be made.

Beginning with Figure 4.16, the velocity comparisons are given. Where an average velocity value was computed because there was more than one gage at the designated range and depth, this average value is plotted with a vertical bar indicating the actual data spread. A single point with no bar means either that only one value was obtained or that the data spread was not detectable on the scale of the plots. Actual values may be obtained by referring to the tabulations. Figures 4.16 through 4.21 present vertical velocities versus range for each depth, together with deviations of the predictions, and Figures 4.22 through 4.25 present vertical velocities versus depth for each range. Horizontal velocity peak values versus range, with deviations of the predictions, are given in Figures 4.26 through 4.28, and the same values versus depth are given in Figures 4.29 through 4.32.

Finally, the displacement peak values are given in Figures 4.33 through 4.48. As mentioned previously, experimental values are taken from integrations of the velocity traces, so the data shown here is not independently obtained. Again, averages of the data points are used where there was more than one, with vertical bars to indicate the data spread. Vertical displacements versus range, with separate prediction deviation plots, are shown in Figures 4.33 through 4.37; vertical displacements versus depth are shown in Figures 4.38 through 4.41. The horizontal displacement data is given as functions of range in Figures 4.42 through 4.44, and as functions of depth in Figures 4.45 through 4.48.

C. WAVEFORM COMPARISONS

In a few cases, attempts were made by Field Command (FC) and the Air Force Weapons Laboratory (AFWL) to predict the complete waveform traces to be expected from the gages. This involves superposition of the expected direct induced and airblast induced motions, with appropriate pulse durations of each. The phase relationship of the two signals, or time of arrival of each, must also be predicted.

These predicted waveforms are compared with actual recorded traces from Event 1, where both are available, in Figures 4.49 through 4.62. Although some features of the waveforms are predicted with remarkable accuracy, it is obvious that our understanding of all aspects of ground motion is not sufficient that reliable waveform predictions can be made in every case.

D. OBSERVATIONS ON EVENT 1 COMPARISONS

In Tables 4.4, 4.5, 4.6, and 4.7, observations from the comparisons of data and predictions shown in the plots are made separately for the four predicting agencies. In some cases the amount of comparable data was too sparse to indicate any obvious trends. These cases are noted in the tables. A final observation summary covering all agencies is given in Table 4.8.

It should be mentioned here that there is no intent in this summary to imply that any one set of predictions is better or worse than any other. It is recognized that the predictions were made for different purposes (e.g., for gage range setting) and with varying degrees of effort involved. Rather, it is hoped that the reader will gain an overall feeling for the accuracy with which ground motion predictions can be made, and an appreciation for the care that must be taken to prepare a good prediction. This feeling and appreciation should serve as background for the preparation and evaluation of predictions for future tests.

1. AFWL Predictions. The Air Force Weapons Laboratory predicted airblast induced vertical and horizontal accelerations, velocities, and displacements. They also predicted direct induced vertical velocities and displacements. Observations on comparisons of these predictions with experimental data, along with references to the figures from which the observations were made, are given in Table 4.4. The AFWL predictions for direct induced motions were generally higher than the

data. It will be recalled that these predictions were based on an estimate of anticipated crater volume. The predicted crater volume was 105,000 cubic feet, whereas actual crater volume was 152,000 cubic feet. It may be speculated that the AFWL predictions would have been even higher, and hence further from the measured values, if the crater volume prediction had been closer.

2. RDA Predictions. R and D Associates predicted airblast induced and direct induced vertical velocities and displacements. Predictions were also made of horizontal velocity and displacement peaks. These latter were not specified as arising from airblast or direct induced motions. Observations on comparisons of these predictions with the experimental data are given in Table 4.5. The airblast induced motions, as predicted by RDA, did not take into account the influence of the water table at a depth of approximately two meters (6 - 8 feet). The experimental data, however, show a substantial change in airblast induced motions across this boundary, and it shows up on the data and deviation plots. The RDA predictions are generally low above the water table and high below it.

3. FC Predictions. Field Command predicted only direct induced vertical and horizontal velocities. Very few predictions were made, and these were intended only as spot checks as to whether or not other predictions were reasonable. The approach was empirical and intuitive; however, results were excellent in that they came quite close in most cases to the measured velocity peaks. Observations on the comparisons are given in Table 4.6.

4. WES Predictions. Waterways Experiment Station predicted direct induced vertical and horizontal accelerations and velocities. Observations on comparisons of these predictions with the experimental data appear in Table 4.7. It would be expected that these predictions, because they were made for the purpose of setting the gage ranges, would tend to be conservative; that is, somewhat higher than the measured peak values. Study of the plotted comparisons indicates that this is indeed the case.

Table 4.1. Pre-DICE THROW II, Event 1 Acceleration Data with Prediction and Deviations

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, g's				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
12.2	0.5	V	0	1940.	1940.	890.	890.	-/-	10000.	-/-	-	-/-	-415.	-/-	-
12.2	0.5	H	0	700.	700.	280.	280.	-/-	5500.	-/-	-	-/-	-686.	-/-	-
12.2	1.8	V	0	1610.	1610.	750.	750.	-/-	10000.	-/-	-	-/-	-521.	-/-	-
12.2	1.8	H	0	1410.	1410.	490.	490.	-/-	4500.	-/-	-	-/-	-219.	-/-	-
12.2	3.7	V	0	*	*	-	-	-/-	10000.	-/-	-	-/-	-	-/-	-
12.2	3.7	H	0	*	*	-	-	-/-	4500.	-/-	-	-/-	-	-/-	-
18.3	0.5	V	0	115.		330.									
18.3	0.5	V	120	195.	138.	280.	275.	-/-	2300.	-/-	-	-/-	-1567.	-/-	-
18.3	0.5	V	240	105.		215.									
18.3	0.5	H	0	31.		-									
18.3	0.5	H	120	67.	45.	35.	35.	-/-	1300.	-/-	-	-/-	-2789.	-/-	-
18.3	0.5	H	240	38.		-									
18.3	1.8	V	0	81.	81.	58.	58.	-/-	2000.	-/-	-	-/-	-2369.	-/-	-
18.3	1.8	H	0	36.5	36.5	25.	25.	-/-	1100.	-/-	-	-/-	-2914.	-/-	-
18.3	3.7	V	0	7000.	7000.	6500.	6500.	-/-	2000.	-/-	-	-/-	71.4	-/-	-
18.3	3.7	H	0	5100.**	5100.**	4200.**	4200.**	-/-	1100.	-/-	-	-/-	78.4	-/-	-
18.3	6.1	V	0	7500.**	7500.**	5800.**	5800.**	-/-	2000.	-/-	-	-/-	73.3	-/-	-
18.3	6.1	H	0	*	*	*	*	-/-	1100.	-/-	-	-/-	-	-/-	-
18.3	9.1	V	0	*	*	*	*	-/-	2000.	-/-	-	-/-	-	-/-	-
18.3	9.1	H	0	*	*	*	*	-/-	1100.	-/-	-	-/-	-	-/-	-
24.4	3.7	V	0	2950.		-									
24.4	3.7	V	120	*	2950.	*	-	-/4.68	700.	-/-	-	-/-	76.3	-/-	-
24.4	3.7	V	240	*		*									

Table 4.1. Pre-DICE THROW II, Event 1 Acceleration Data with Prediction and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, g's				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
24.4	3.7	H	0	*		*									
24.4	3.7	H	120	*	1590.**	*	1500.**	-/-	400.	-/-	-	-/-	74.8	-/-	-
24.4	3.7	H	240	1590.**		1500.**									
24.4	6.1	V	0	*		*									
24.4	6.1	V	120	*	2200.	*	-	-/4.44	700.	-/-	-	-/-	68.2	-/-	-
24.4	6.1	V	240	2200.		-									
24.4	6.1	H	0	*		*									
24.4	6.1	H	120	*	1600.	*	-	-/-	400.	-/-	-	-/-	75.0	-/-	-
24.4	6.1	H	240	1600.		-									
24.4	9.1	V	0	*		*									
24.4	9.1	V	120	1400.	1400.	-	3000.**	-/4.28	700.	-/-	-	-/99.9	50.0	-/-	-
24.4	9.1	V	240	2500.**		3000.**									
24.4	9.1	H	0	*		*									
24.4	9.1	H	120	1500.**	1450.**	-	2400.**	-/-	400.	-/-	-	-/-	72.4	-/-	-
24.4	9.1	H	240	1400.**		2400.**									
24.4	12.2	V	0	*	*	*	*	-/3.74	700.	-/-	-	-/-	-	-/-	-
24.4	12.2	H	0	1450.	1450.	700.	700.	-/-	400.	-/-	-	-/-	72.4	-/-	-
33.5	0.5	V	0	320.	320.	590.	590.	-/-	300.	-/-	-	-/-	6.25	-/-	-
33.5	0.5	H	0	330.	330.	200.	200.	-/-	170.	-/-	-	-/-	48.5	-/-	-
33.5	3.7	V	0	550.**		740.**									
33.5	3.7	V	60	150.		68.									
33.5	3.7	V	120	500.**	265.	970.**	134.	-/-	200.	-/-	-	-/-	24.5	-/-	-
33.5	3.7	V	180	380.		200.									
33.5	3.7	V	240	*		*									
33.5	3.7	V	300	810.**		750.**									

Table 4.1. Pre-DICE THROW II, Event 1 Acceleration Data with Prediction and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, g's				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
33.5	3.7	H	0	600.**		900.**									
33.5	3.7	H	60	500.**		620.**									
33.5	3.7	H	120	*		*									
33.5	3.7	H	180	*	330.		270.	-/-	150.	-/-	-	-/-	54.6	-/-	-
33.5	3.7	H	240	330.		270.									
33.5	3.7	H	300	530.**		-									
33.5	6.1	V	0	830.**		-									
33.5	6.1	V	120	500.**	665.**	970.**	970.**	-/-	200.	-/-	-	-/-	69.9	-/-	-
33.5	6.1	V	240	*		*									
33.5	6.1	H	0	330.**		-									
33.5	6.1	H	120	*	330.	*	270.	-/-	150.	-/-	-	-/-	54.6	-/-	-
33.5	6.1	H	240	330.		270.									
33.5	9.1	V	0	310.	310.	260.	260.	-/-	200.	-/-	-	-/-	35.5	-/-	-
33.5	9.1	H	0	195.	195.	155.	155.	-/-	150.	-/-	-	-/-	23.1	-/-	-
33.5	12.2	V	0	630.	630.	320.	320.	-/-	200.	-/-	-	-/-	68.3	-/-	-
33.5	12.2	H	0	380.	380.	260.	260.	-/-	150.	-/-	-	-/-	60.5	-/-	-
48.8	0.5	V	0	40.	40.	148.	148.	-/144.	140.	-/-	-	-/2.70	-250.	-/-	-
48.8	0.5	H	0	28.	28.	13.	13.	-/-	45.	-/-	-	-/-	-60.7	-/-	-
48.8	3.7	V	0	59.	59.	78.	78.	-/5.34	75.	-/-	-	-/93.2	-27.1	-/-	-
48.8	3.7	H	0	118.**	118.**	250.**	250.**	-/-	40.	-/-	-	-/-	66.1	-/-	-
91.4	0.5	V	0	31.	31.	73.	73.	-/35.	60.	-/-	-	-/52.1	-93.6	-/-	-
91.4	0.5	H	0	9.9	9.9	8.6	8.6	-/-	15.	-/-	-	-/-	-51.5	-/-	-
91.4	1.8	V	0	6.2	6.2	12.8	12.8	-/-	25.	-/-	-	-/-	-303.	-/-	-
91.4	1.8	H	0	6.2	6.2	4.4	4.4	-/-	8.	-/-	-	-/-	-29.0	-/-	-

Table 4.1. Pre-DICE THROW II, Event 1 Acceleration Data with Preaiction and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, g's				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
91.4	3.7	V	0	23.	23.	10.5	10.5	-/2.17	25.	-/-	-	-/79.3	-8.70	-/-	-
91.4	3.7	H	0	15.	15.	15.	15.	-/-	8.	-/-	-	-/-	46.7	-/-	-
91.4	6.1	V	0	23.	23.	22.	22.	-/2.06	-	-/-	-	-/90.υ	-	-/-	-
91.4	6.1	H	0	29.	29.	19.5	19.5	-/-	8.	-/-	-	-/-	72.4	-/-	-

* No peak data
** Out of band

Table 4.2. Pre-DICE THROW II, Event 1 Velocity Data with Predictions and Deviations

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
24.4	0.5	V	0	4.5		4.2									
24.4	0.5	V	120	4.3	4.8	3.6	4.9	3.1/5.5	5.49	3.05/3.96	3.05	36.1/-12.1	-15.1	36.1/18.7	36.1
24.4	0.5	V	240	5.5		6.8									
24.4	0.5	H	0	2.6		1.8									
24.4	0.5	H	120	2.2	2.1	-	1.3	3.17/-	3.51	2.38/-	1.52	-48.8/-	-64.8	-11.7/-	28.6
24.4	0.5	H	240	1.6		0.8									
24.4	1.8	V	0	2.0		1.2									
24.4	1.8	V	120	1.7	2.1	-	1.5	-/-	3.66	1.68/0.94	-	-/-	-76.8	18.8/[illegible]	-
24.4	1.8	V	240	2.5		1.9									
24.4	1.8	H	0	2.0		0.7									
24.4	1.8	H	120	1.9	1.8	-	0.65	-/-	3.51	2.19/-	-	-/-	-91.8	-19.7/-	-
24.4	1.8	H	240	1.6		0.6									
33.5	0.5	V	0	1.8		6.9									
33.5	0.5	V	60	2.6		4.2									
33.5	0.5	V	120	2.8	2.4	3.9	4.8	-/-	3.05	1.37/3.20	-	-/-	-25.5	43.6/32.6	-
33.5	0.5	V	180	2.2		3.8									
33.5	0.5	V	240	3.0		5.0									
33.5	0.5	V	300	2.2		4.7									
33.5	0.5	H	0	1.1		0.72									
33.5	0.5	H	60	1.3		0.76									
33.5	0.5	H	120	1.2	1.2	0.95	0.73	-/-	1.83	1.22/-	-	-/-	-57.8	-5.20/-	-
33.5	0.5	H	180	1.1		0.70									
33.5	0.5	H	240	1.1		0.74									
33.5	0.5	H	300	1.2		0.51									
33.5	1.8	V	0	1.1		1.4									
33.5	1.8	V	120	0.75	1.1	0.35	1.3	-/-	2.13	1.01/0.82	-	-/-	-103.	3.80/35.9	-
33.5	1.8	V	240	1.3		2.1									

Table 4.2. Pre-DICE THROW II, Event 1 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
33.5	1.8	H	0	0.81	0.89	0.60	0.57	-/-	1.83	1.19/-	-	-/-	-106.	-33.7/-	-
33.5	1.8	H	120	0.92		0.61									
33.5	1.8	H	240	0.95		0.50									
33.5	3.7	V	0	1.3	1.3	0.2	0.2	-/-	1.52	0.76/0.55	-	-/-	-16.9	41.5/-175.	-
33.5	3.7	H	0	1.15/0.95	1.15/0.95	0.5	0.5	-/-	1.83	1.13/-	-	-/-	-59.1 -92.6	1.70/- -18.9/-	-
48.8	0.5	V	0	1.0	0.97	4.8*	4.2	0.98/4.7	1.52	0.76/1.83	1.52	-1.0/-12.4	-56.7	21.6/56.4	-88.7
48.8	0.5	V	120	0.8		4.1*									
48.8	0.5	V	240	1.1		3.7*									
48.8	0.5	H	0	0.22	0.30	0.22	.20	1.01/-	0.82	0.59/-	0.61	-237./-	-173.	-96.7/-	-103.3
48.8	0.5	H	120	0.21		0.10									
48.8	0.5	H	240	0.46		0.29									
48.8	1.8	V	0	0.45	0.46	2.1*	1.81	-/-	1.07	0.56/0.67	-	-/-	-133.	-21.7/63.0	-
48.8	1.8	V	120	0.23		0.42									
48.8	1.8	V	240	0.70		2.9*									
48.8	1.8	H	0	0.42	0.48	0.34	0.32	-/-	0.82	0.58/-	-	-/-	-70.8	-20.8/-	-
48.8	1.8	H	120	0.61		0.29									
48.8	1.8	H	240	0.41		-									
48.8	3.7	V	0	0.22	0.30	0.18	0.20	1.14/0.4	0.76	0.43/0.40	0.30	-280./-100.	-153.	-43.3/-100.	0
48.8	3.7	V	120	0.34		0.14									
48.8	3.7	V	240	0.34		0.28									
48.8	3.7	H	0	0.35	0.41	0.26	0.21	1.13/-	0.82	0.55/-	0.61	-176/-	-100.	-34.1/-	-48.4
48.8	3.7	H	120	0.49		0.31									
48.8	3.7	H	240	0.32		0.15/0.12									
48.8	6.1	V	0	0.41	0.41	0.14	0.14	-/0.40	0.49	0.37/0.29	-	-/-186.	-19.5	9.8/-107.	-
48.8	6.1	H	0	0.31/0.30	0.31	0.29	0.29	1.13/-	0.82	0.49/-	-	-265./-	-164.	-58.1/-	-
48.8	9.1	V	0	0.45	0.45	0.11	0.11	-/0.37	0.30	0.23/0.80	-	-/-236.	33.3	48.9/-627.	-

Table 4.2. Pre-DICE THROW II, Event 1 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
48.8	9.1	H	0	0.48/0.29	0.48/0.29	0.30	0.30	1.13/-	0.82	0.44/	-	-135./- -290./-	-70.8 -183.	8.3/- -51.7/-	- -
70.1	0.5	V	0	0.50		1.62									
70.1	0.5	V	120	0.60	0.59	2.31*	1.84	0.53/2.1	0.76	0.38/1.07	-	10.2/-12.5	-28.8	35.6/41.8	-
70.1	0.5	V	240	0.68		1.58									
70.1	0.5	H	0	0.26		0.21									
70.1	0.5	H	120	0.24	0.22	0.19	0.17	0.55/-	0.43	0.35/-	-	-150./-	-95.5	-59.1/-	-
70.1	0.5	H	240	0.17		0.10									
70.1	1.8	V	0	0.23	0.23	1.05	1.05	-/-	0.55	0.36/0.49	-	-/-	-139.	-56.5/53.3	-
70.1	1.8	H	0	0.27	0.27	0.20	0.20	-/-	0.43	0.34/-	-	-/-	-59.3	-25.9/-	-
70.1	3.7	V	0	0.19		0.05									
70.1	3.7	V	120	0.30	0.27	0.06	0.06	0.61/0.27	0.40	0.24/0.30	-	-125./-350.	-48.1	11.1/-400.	-
70.1	3.7	V	240	0.31		0.08									
70.1	3.7	H	0	0.31		0.19									
70.1	3.7	H	120	0.26	0.27	0.15	0.15	0.58/-	0.43	0.33/-	-	-115./-	-59.3	-22.2/-	-
70.1	3.7	H	240	0.23		0.12									
70.1	6.1	V	0	0.23	0.23	0.05	0.05	-/0.27	0.27	0.18/0.22	-	-/-440.	-17.4	21.7/-340.	-
70.1	6.1	H	0	0.27	0.27	0.19	0.19	0.58/-	0.43	0.29/-	-	-115/-	-59.3	-11.1/-	-
91.4	0.5	V	0	0.30	0.30	0.71	0.71	0.30/1.2	0.49	0.23/0.61	-	0.0/-63.4	-63.3	23.3/14.1	-
91.4	0.5	H	0	0.13	0.13	0.10	0.10	0.34/-	0.21	0.25/-	-	-162./-	-61.5	-92.3/-	-
91.4	1.8	V	0	0.16	0.16	0.37	0.37	-/-	0.37	0.20/0.37	-	-/-	-131.	-25.0/0.0	-
91.4	1.8	H	0	0.20	0.20	0.12	0.12	-/-	0.21	0.24/-	-	-/-	-5.0	-20.0/-	-
91.4	3.7	V	0	0.14	0.14	0.05	0.05	0.40/0.15	0.26	0.16/0.23	-	-183./-200.	-85.7	-14.3/-360.	-
91.4	3.7	H	0	0.21	0.21	0.11	0.11	0.37/-	0.21	0.23/-	-	-76.2/-	0.0	-9.5/-	-
91.4	6.1	V	0	0.14	0.14	0.07	0.07	-/0. 5	0.17	0.11/0.18	-	-/-114.	-21.4	21.4/-157.	-

Table 4.2. Pre-DICE THROW II, Event 1 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
91.4	6.1	H	0	0.19	0.19	0.10	0.10	0.37/-	0.21	0.21/-	-	-94.7/-	-10.5	-10.5/-	-
121.9 121.9 121.9	0.5 0.5 0.5	V V V	0 120 240	0.09 0.12 0.15	0.12	0.19 0.34 0.25	0.26	0.18/0.58	0.40	0.18/0.37	-	-50./-123.	-233.	-50.0/-42.3	-
121.9 121.9 121.9	0.5 0.5 0.5	H H H	0 120 240	0.14 0.17 0.15	0.15	0.08 0.07 0.06	0.07	0.18/-	0.18	0.18/-	-	-20.0/-	-20.0	-20.0/-	-
121.9 121.9 121.9	1.8 1.8 1.8	V V V	0 120 240	0.08 0.10 0.08	0.09	0.07 0.07 0.07	0.07	-/-	0.30	0.16/0.25	-	-/-	-233.	-77.8/-257.	-
121.9 121.9 121.9	1.8 1.8 1.8	H H H	0 120 240	0.17 0.22 0.15	0.18	0.09 0.07 0.06	0.07	-/-	0.14	0.17/-	-	-/-	22.2	5.6/-	-
121.9 121.9	3.7 3.7	V V	0 120	0.10 0.11	0.10	0.07 0.07	0.07	0.23/0.09	0.22	0.10/0.19	-	-129./-29.	-120.	0/-171.	-
121.9 121.9	3.7 3.7	H H	0 120	0.18 0.15	0.17	0.09 0.07	0.08	0.21/-	0.12	0.16/-	-	-23.5/-	29.4	5.9/-	-
121.9	6.1	V	0	0.09	0.09	0.05	0.05	-/0.09	0.15	0.06/0.14	-	-/-80.0	-66.7	33.3/-180.	-
121.9	6.1	H	0	0.11	0.11	0.08	0.08	0.21/-	0.12	0.14/-	-	-90.9/-	-9.1	-27.3/-	-
121.9	9.1	V	0	0.20	0.20	0.07	0.07	-/-	0.12	0.05/0.11	-	-/-	40.0	75.0/-57.1	-
121.9	9.1	H	0	0.27	0.27	0.05	0.05	0.21/-	0.12	0.13/-	-	22.2/-	55.6	51.9/-	-
121.9	12.1	V	0	0.10	0.10	0.06	0.06	-/0.09	0.12	0.04/0.10	-	-/-63.6	-26.3	57.9/-81.8	-
121.9	12.1	H	0	0.17	0.17	0.06	0.06	0.21/-	0.12	0.11/-	-	-23.5/-	29.4	35.3/-	-
182.9	0.5	V	0	0.06	0.06	0.18	0.18	-/-	0.34	0.12/0.20	-	-/-	-467.	-107./-11.1	-
182.9	0.5	H	0	0.12	0.12	0.07	0.07	-/-	0.13	0.11/-	-	-/-	-8.3	8.3/-	-

Table 4.2. Pre-DICE THROW II, Event 1 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negativ , m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
1o2.9	1.8	V	0	0.05	0.05	0.09	0.09	-/-	0.24	0.08/0.15	-	-/-	-410.	-70.2/-66.7	-
182.9	1.8	H	0	0.18	0.18	0.06	0.06	-/-	0.10	0.10/-	-	-/-	44.4	44.4/-	-
182.9	3.7	V	0	0.04	0.04	0.08	0.08	-/-	0.18	0.05/0.12	-	-/-	-350.	-25.0/-55.8	-
182.9	3.7	H	0	0.22	0.22	0.13	0.13	-/-	0.09	0.09/-	-	-/-	59.1	59.1/-	-

*Signal went to band-edge

Table 4.3. Pre-DICE THROW II, Event 1 Displacement Data with Predictions and Deviations

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
24.4	0.5	V	0	68.		-									
24.4	0.5	V	120	42.	68.	-	7.5	145./5.1	-	64./4.3	-	-113./32.	-	5.88/42.7	-
24.4	0.5	V	240	94.		7.5									
24.4	0.5	H	0	92.		-									
24.4	0.5	H	120	85.	79.	-	-	132./-	-	85.3/-	-	-66.6/-	-	-7.6/-	-
24.4	0.5	H	240	61.		-									
24.4	1.8	V	0	61.		-									
24.4	1.8	V	120	-	70.	-	-	-/-	-	57.9/1.0	-	-/-	-	17.3/-	-
24.4	1.8	V	240	79.		-									
24.4	1.8	H	0	73.		-									
24.4	1.8	H	120	60.	66.	-	-	-/-	-	82.3/-	-	-/-	-	-24.1/-	-
24.4	1.8	H	240	66.		-									
33.5	0.5	V	0	-		-									
33.5	0.5	V	60	22.		4.6									
33.5	0.5	V	120	13.	27.	4.5	4.4	-/-	-	24.1/4.3	-	-/-	-	9.4/2.3	-
33.5	0.5	V	180	22.		4.1									
33.5	0.5	V	240	59.		-									
33.5	0.5	V	300	17.		6.1									
33.5	0.5	H	0	31.5		-									
33.5	0.5	H	60	36.		-									
33.5	0.5	H	120	31.	34.	-	-	-/-	-	36.6/-	-	-/-	-	-6.4/-	-
33.5	0.5	H	180	31.		-									
33.5	0.5	H	240	36.		-									
33.5	0.5	H	300	41.		-									
33.5	1.8	V	0	16.		-									
33.5	1.8	V	120	12.5	16.	-	2.5	-/-	-	23.2/1.4	-	-/-	-	-43.2/44.0	-
33.5	1.8	V	240	20.		2.5									
33.5	1.8	H	0	25.		-									
33.5	1.8	H	120	25.	27.	-	-	-/-	-	33.5/-	-	-/-	-	-25.5/-	-
33.5	1.8	H	240	30.		-									

Table 4.3. Pre-DICE THROW II, Event 1 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
33.5	3.7	V	0	-	-	-	-	-/-	-	22.6/0.5	-	-/-	-	-/-	-
33.5	3.7	H	0	31.	31.	-	-	-/-	-	29.6/-	-	-/-	-	4.5/-	-
48.8 48.8 48.8	0.5 0.5 0.5	V V V	0 120 240	3.5 4.0 5.5	4.3	8.2 5.9 9.1	7.7	18.1/4.3	-	7.0/3.0	-	-321./44.	-	-62.8/61.0	-
48.8 48.8 48.8	0.5 0.5 0.5	H H H	0 120 240	5.5 5.5 12.9	8.0	- - -	-	16.5/-	-	11.9/-	-	-106./-	-	-48.8/-	-
48.8 48.8 48.8	1.8 1.8 1.8	V V V	0 120 240	2.1 3.5 0.41	2.0	3.2 0.4 0.41	1.3	-/-	-	6.7/1.4	-	-/-	-	-235./-7.7	-
48.8 48.8 48.8	1.8 1.8 1.8	H H H	0 120 240	9.8 7.2 10.0	9.0	- - -	-	-/-	-	11.6/-	-	-/-	-	-28.9/-	-
48.8 48.8 48.8	3.7 3.7 3.7	V V V	0 120 240	2.8 3.3 7.1	4.4	- - -	-	7.3/0.8	-	6.4/0.7	-	-65./-	-	-45.5/-	-
48.8 48.8 48.8	3.7 3.7 3.7	H H H	0 120 240	7.2 7.0 3.2	5.8	- - -	-	7.4/-	-	11.0/-	-	-27.6/-	-	-89.7/-	-
48.8	6.1	V	0	2.4	2.4	-	-	3.5/0.8	-	5.8/0.4	-	-45./-	-	-142./-	-
48.8	6.1	H	0	6.5	6.5	-	-	3.6/-	-	9.8/-	-	44.6/-	-	-50.8/-	-
48.8	9.1	V	0	1.8	1.8	-	-	1.5/0.8	-	5.5/0.3	-	19./-	-	-206./-	-
48.8	9.1	H	0	5.9	5.9	-	-	1.5/-	-	7.9/-	-	74.6/-	-	-33.9/-	-
70.1 70.1 70.1	0.5 0.5 0.5	V V V	0 120 240	- - -	-	2.5 3.5 2.4	2.8	5.5/3.2	-	2.5/2.1	-	-/-14.3	-	-/25.0	-

Table 4.3. Pre-DICE THROW II, Event 1 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
70.1	0.5	H	0	3.8		-									
70.1	0.5	H	120	3.4	3.3	-	-	5.6/-	-	4.3/-	-	-69.7/-	-	-30.3/-	-
70.1	0.5	H	240	2.6		-									
70.1	1.8	V	0	-	-	1.8	1.8	-/-	-	2.1/0.9	-	-/-	-	-/50.	-
70.1	1.8	H	0	4.0	4.0	-	-	-/-	-	4.0/-	-	-/-	-	0.0/-	-
70.1	3.7	V	0	1.2		-									
70.1	3.7	V	120	1.0	1.1	-	-	2.5/0.51	-	1.9/0.6	-	-125./-	-	-72.7/-	-
70.1	3.7	V	240	1.1		-									
70.1	3.7	H	0	2.9		-									
70.1	3.7	H	120	2.3	2.4	0.6	0.6	2.5/-	-	3.7/-	-	-4.2/-	-	-54.2/-	-
70.1	3.7	H	240	1.9		0.6									
70.1	6.1	V	0	1.3	1.3	-	-	-/2.3	-	1.7/0.4	-	-/-	-	-30.8/-	-
70.1	6.1	H	0	2.7	2.7	-	-	1.3/-	-	3.5/-	-	51.9/-	-	-29.6/-	-
91.4	0.5	V	0	0.5	0.5	0.76	0.76	-/1.9	-	1.2/1.4	-	-/-150.	-	-140./-84.2	-
91.4	0.5	H	0	1.4	1.4	-	-	2.5/-	-	2.2/-	-	-78.6/-	-	-57.1/-	-
91.4	1.8	V	0	0.59	0.59	0.38	0.38	-/-	-	1.0/0.7	-	-/-	-	-69.5/-84.2	-
91.4	1.8	H	0	1.55	1.55	0.72	0.72	-/-	-	2.0/-	-	-/-	-	-29.0/-	-
91.4	3.7	V	0	0.22/0.60	0.22/0.60	0.24/0.22	0.24/0.22	-/0.5	-	0.9/0.5	-	-/-108. -/-127.	-	-309./-108. -50.0/-127.	-
91.4	3.7	H	0	1.6	1.6	0.6	0.6	1.0/-	-	1.8/-	-	37.5/-	-	-12.5/-	-
91.4	6.1	V	0	0.91	0.91	-	-	-/0.5	-	0.8/0.4	-	-/-	-	12.1/-	-
91.4	6.1	H	0	1.3	1.3	-	-	0.5/-	-	1.7/-	-	61.5/-	-	-30.8/-	-
121.9	0.5	V	0	0.18/0.5		0.36									
121.9	0.5	V	120	0.83	0.4	-	0.4	-/1.0	-	0.6/0.6	-	-/-150.	-	-50.0/-50.0	-
121.9	0.5	V	240	0.2/0.5		0.50									

Table 4.3. Pre-DICE THROW II, Event 1 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
121.9 121.9 121.9	0.5 0.5 0.5	H H H	0 120 240	0.77 0.91 0.81	0.8	- - 0.3	0.3	0.8/-	-	1.1/-	-	0.0/-	-	-37.5/-	-
121.9 121.9 121.9	1.6 1.8 1.8	V V V	0 120 240	0.25/0.55 0.86 0.28/0.66	0.5	0.37 - 0.29	0.3	-/-	-	0.5/0.5	-	-/-	-	0.0/-66.7	-
121.9 121.9 121.9	1.8 1.8 1.8	H H H	0 120 240	0.86 0.92 0.74	0.8	0.48 0.28 0.31	0.4	-/-	-	1.0/-	-	-/-	-	-25.0/-	-
121.9 121.9	3.7 3.7	V V	0 120	0.26/0.51 0.7	0.5	0.33 0.30	0.3	-/-	-	0.5/0.4	-	-/-	-	0.0/-33.3	-
121.9 121.9	3.7 3.7	H H	0 120	0.9 0.82/0.46	0.7	0.58 0.40	0.5	0.5/-	-	0.9/-	-	28.6/-	-	-28.6/-	-
121.9 121.9	6.1 6.1	V V	0 240	- 0.26/0.64	0.5	- 0.4	0.4	-/-	-	0.4/0.3	-	-/-	-	20.0/25.0	-
121.9 121.9	6.1 6.1	H H	0 240	0.75 0.71	0.7	0.56 0.40	0.5	0.3/-	-	0.9/-	-	-/57.1	-	-28.6/-	-
121.9	9.1	V	0	0.85	0.85	-	-	-/-	-	0.4/0.3	-	-/-	-	52.9/-	-
121.9	9.1	H	0	0.61	0.61	0.31	0.31	0.3/-	-	0.8/-	-	50.8/-	-	-31.1/-	-
121.9	12.1	V	0	-	-	-	-	-/-	-	0.3/0.2	-	-/-	-	-/-	-
121.9	12.1	H	0	0.75	0.75	0.43	0.43	0.3/-	-	0.7/-	-	60.0/-	-	6.7/-	-
182.9	0.5	V	0	0.2/0.38	0.3	0.44	0.44	-/-	-	0.3/0.3	-	-/-	-	0.0/31.8	-
182.9	0.5	H	0	0.65	0.65	0.40	0.40	-/-	-	0.5/-	-	-/-	-	23.1/-	-
182.9	1.8	V	0	0.23/0.45	0.3	0.40	0.40	-/-	-	0.2/0.3	-	-/-	-	33.3/25.0	-
182.9	1.8	H	0	0.67	0.67	0.40	0.40	-/-	-	0.5/-	-	-/-	-	25.4/-	-

Table 4.3. Pre-DICE THROW II, Event 1 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
182.9	3.7	V	0	0.19/0.40	0.3	0.30	0.30	-/-	-	0.2/0.3	-	-/-	-	33.3/0.0	-
182.9	3.7	H	0	1.3	1.3	0.89	0.89	-/-	-	0.5/-	-	-/-	-	61.5/-	-

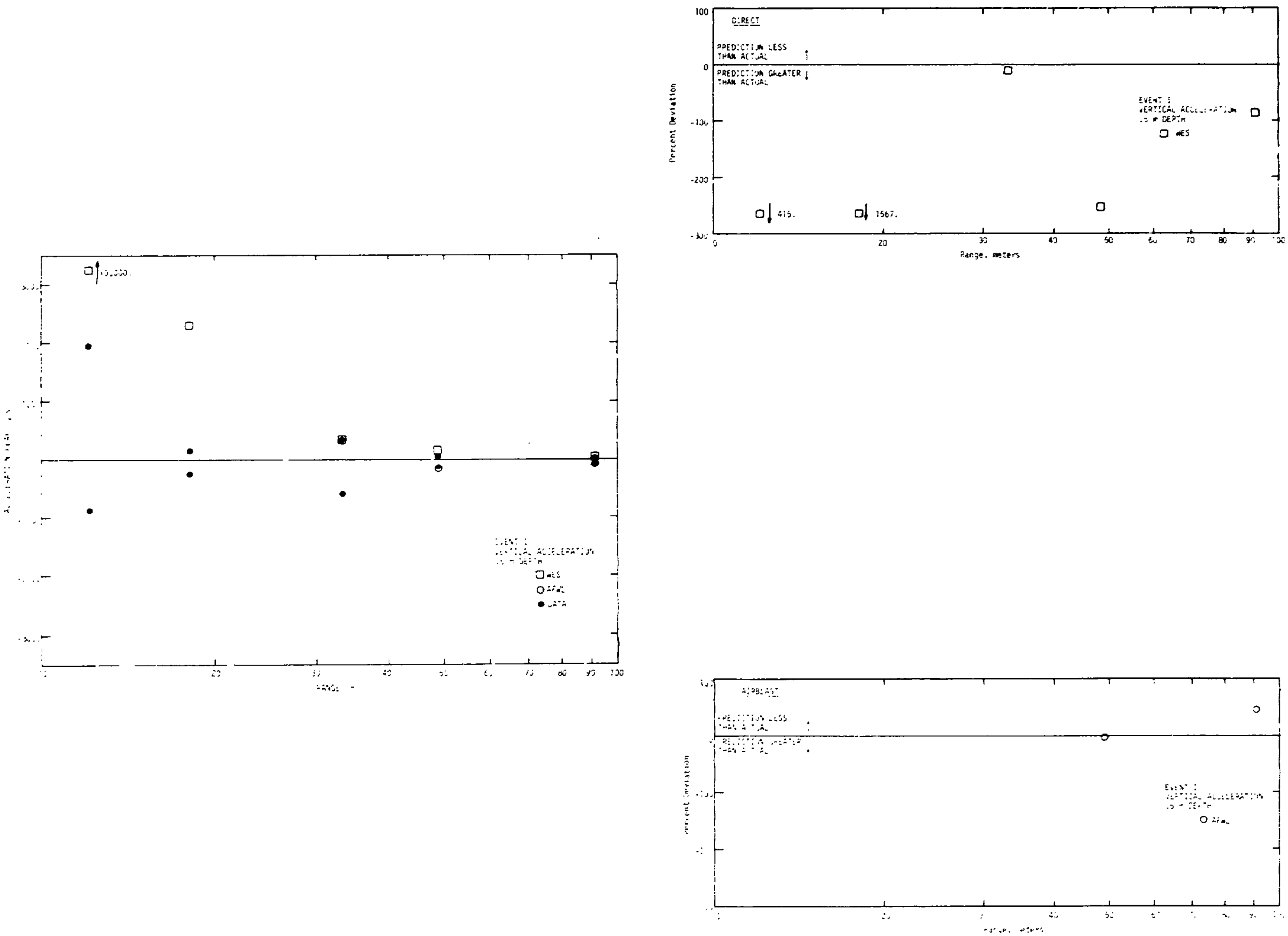


Figure 4.1. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

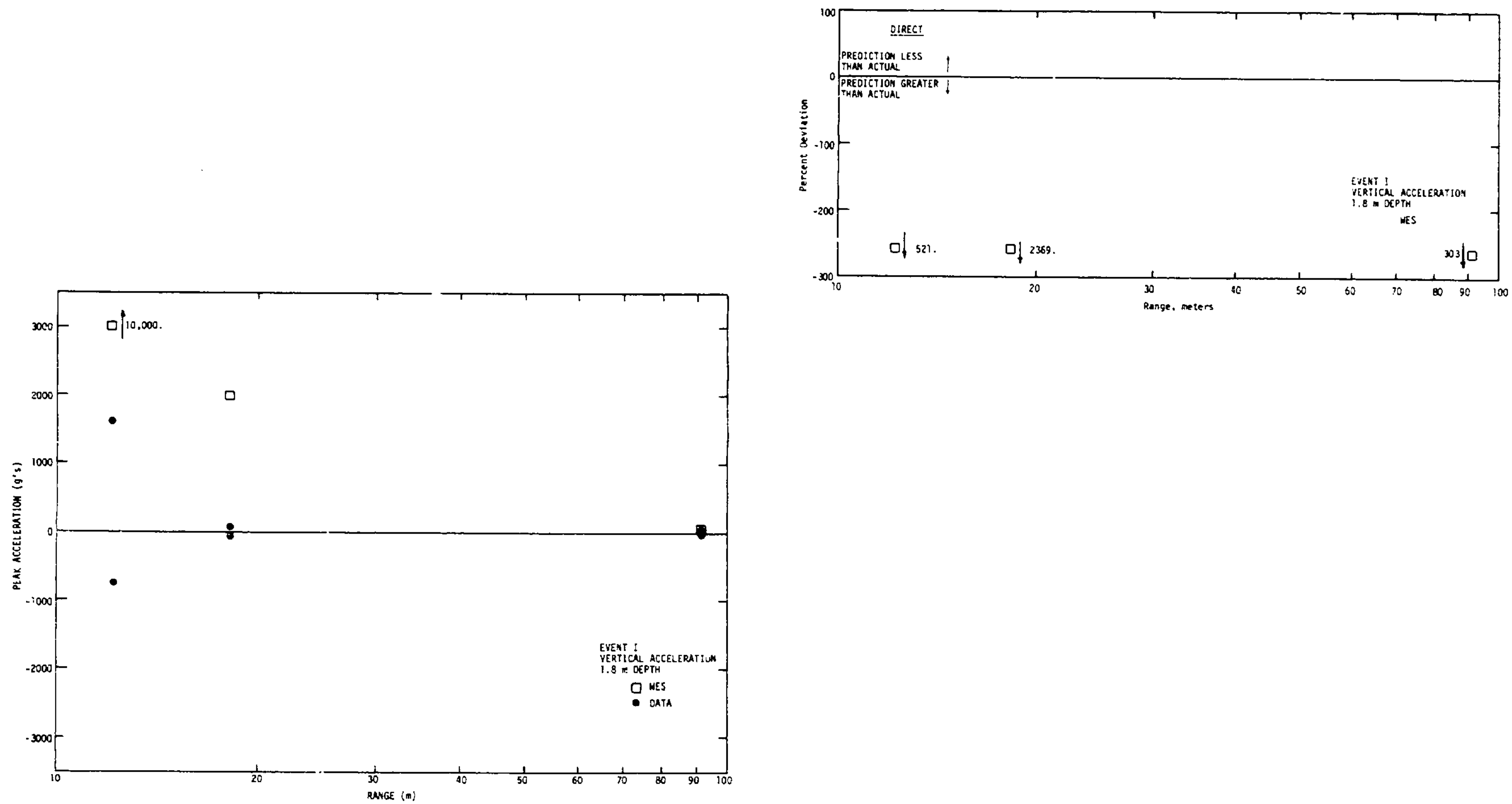


Figure 4.2. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

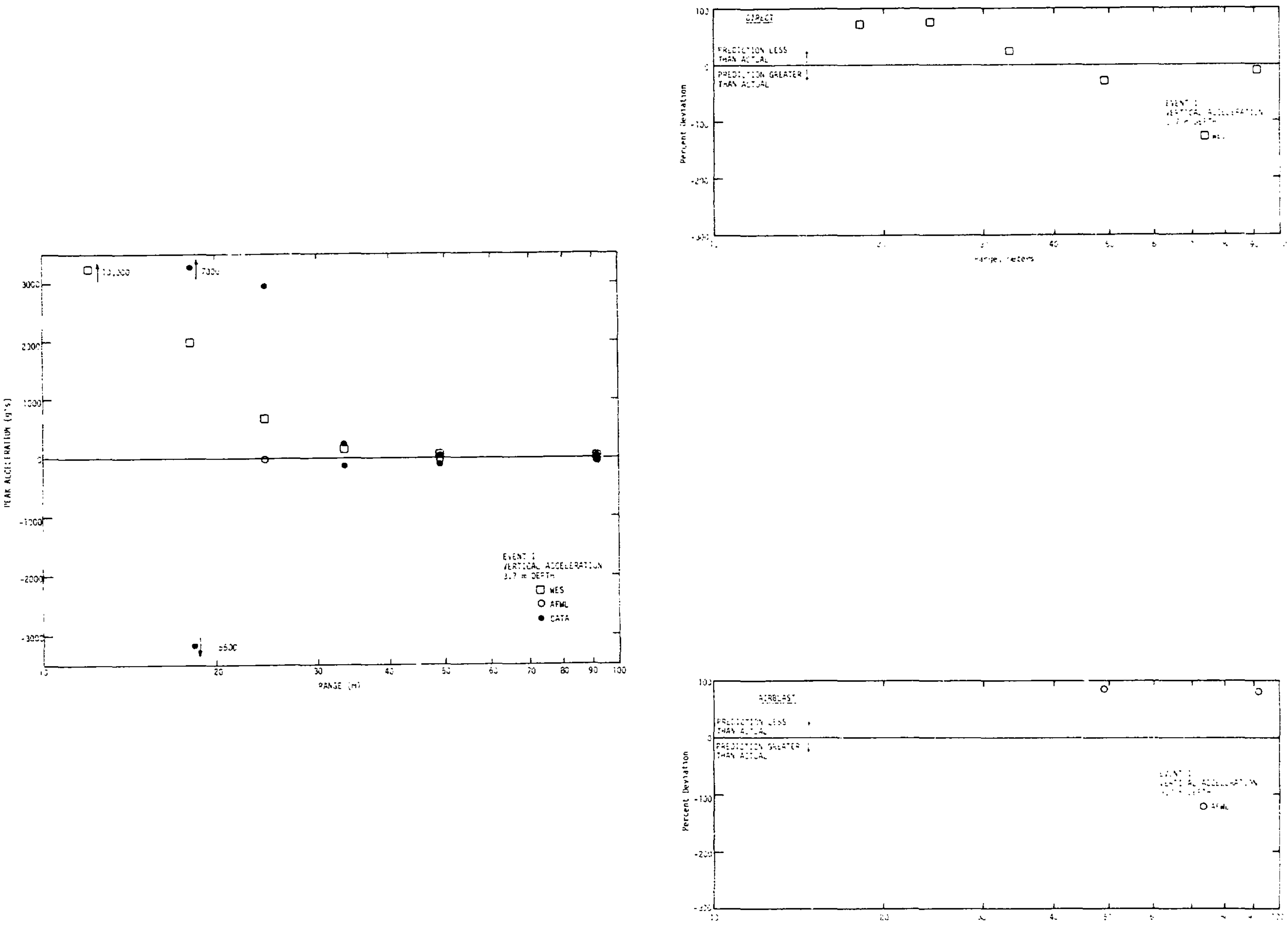


Figure 4.3. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

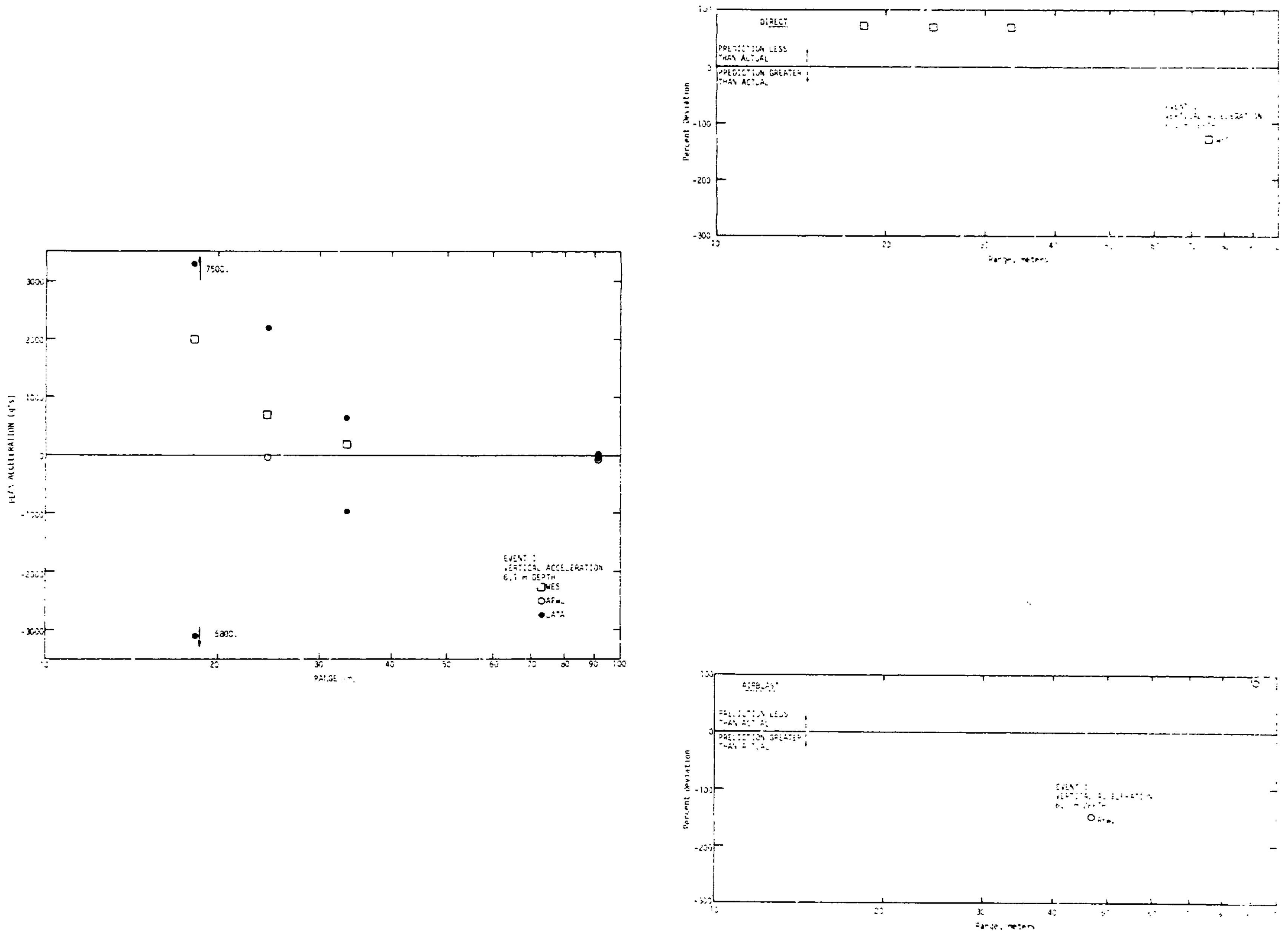


Figure 4.4. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

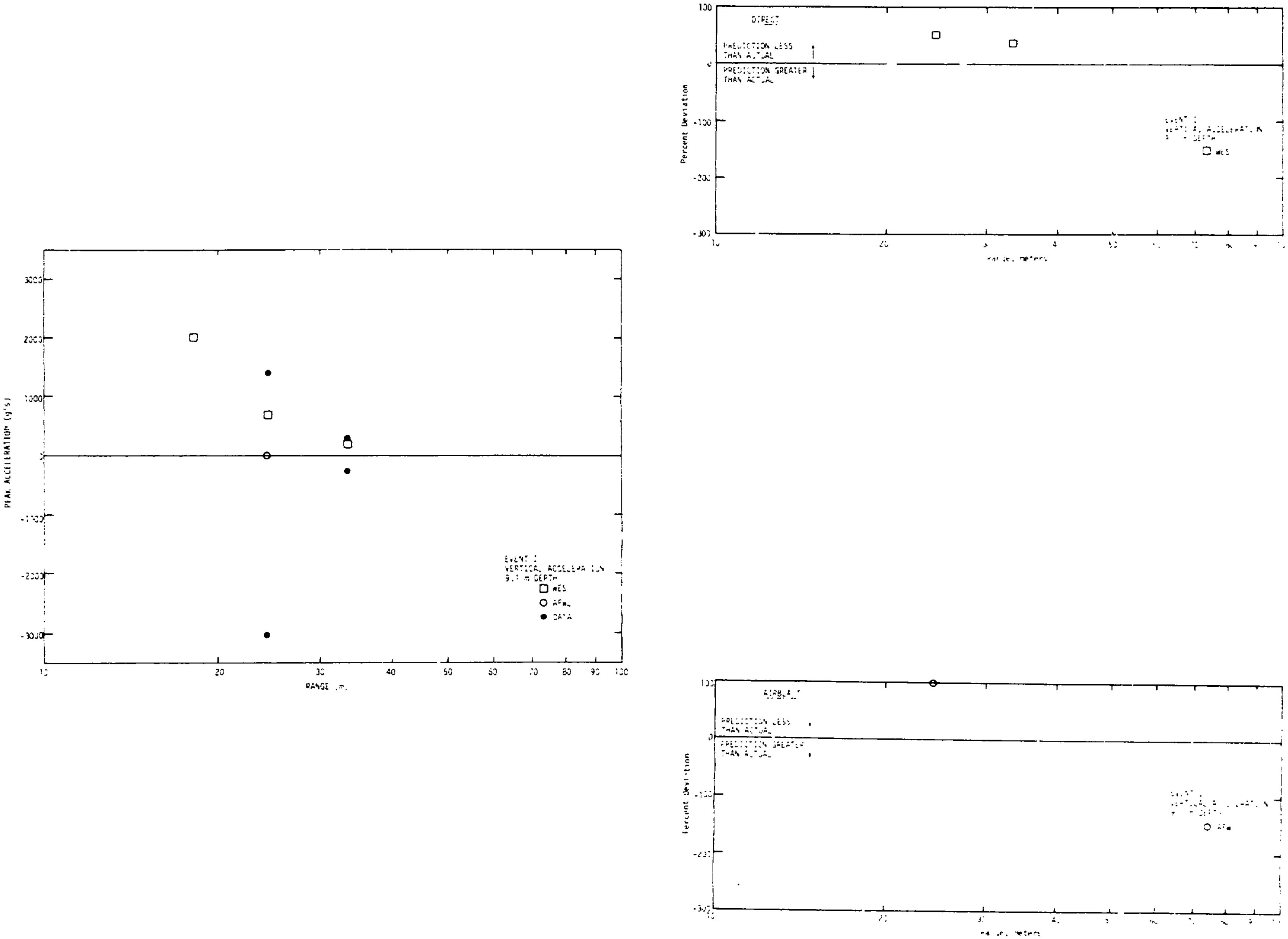


Figure 4.5. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

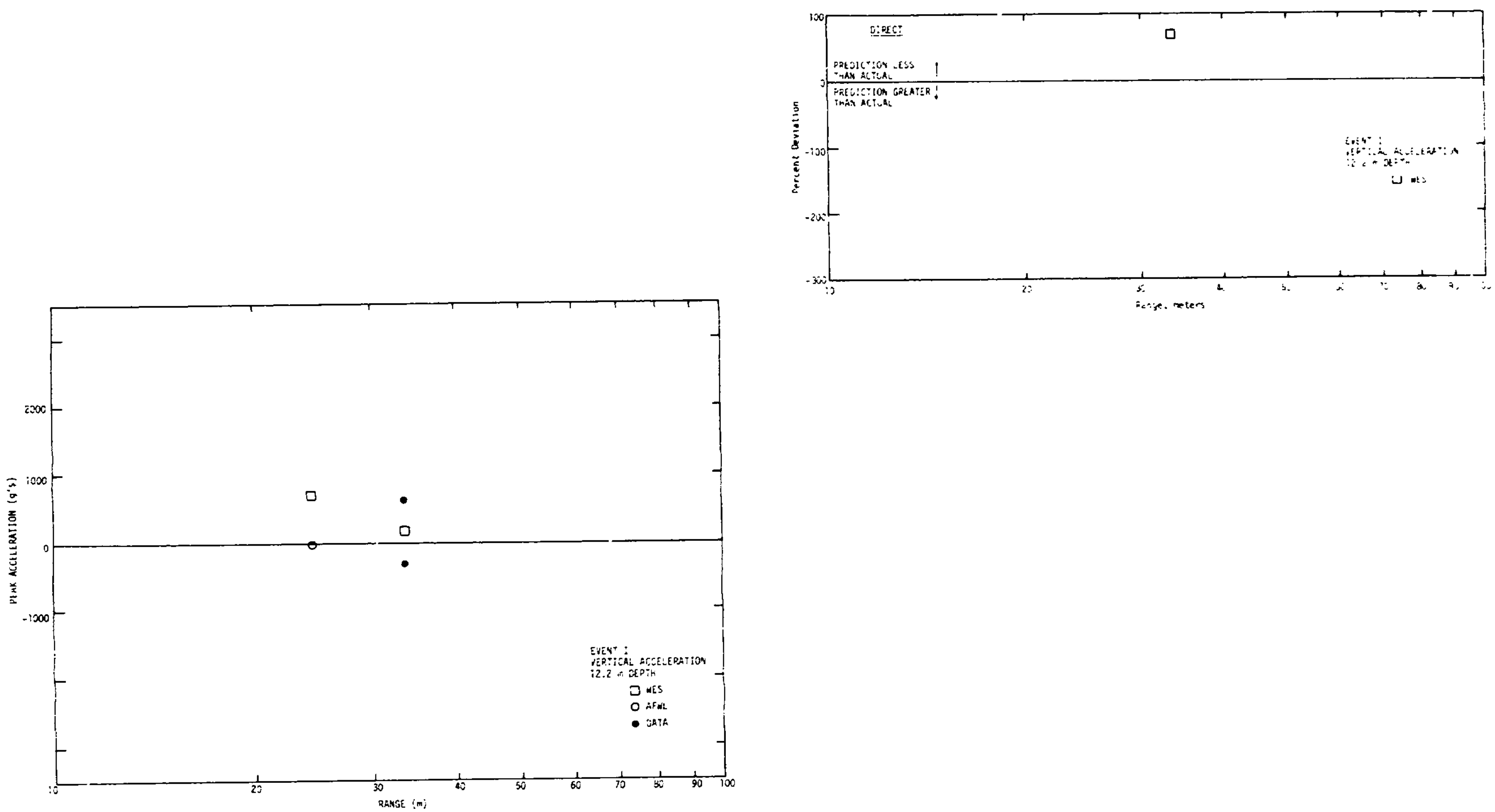


Figure 4.6. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

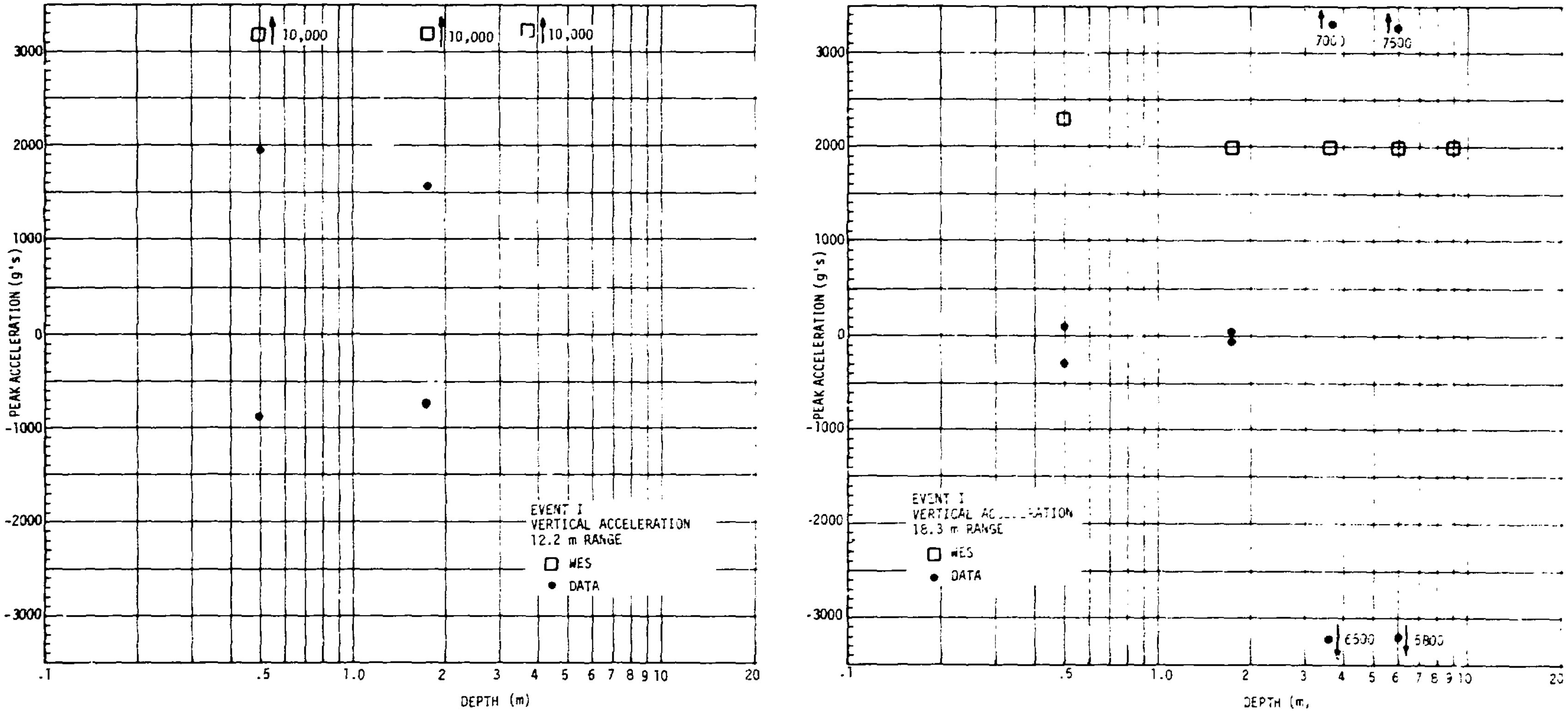


Figure 4.7. Vertical Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 1

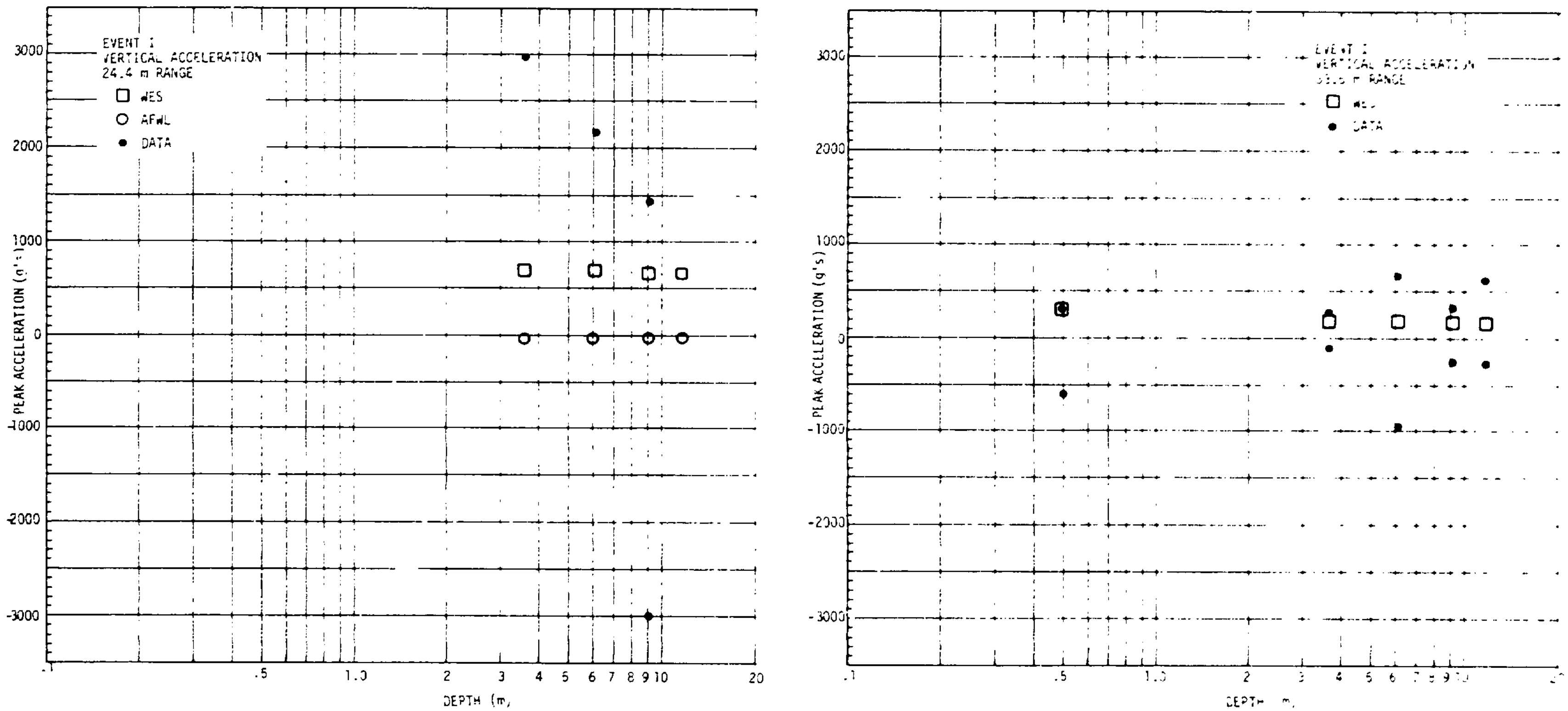


Figure 4.8. Vertical Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 1

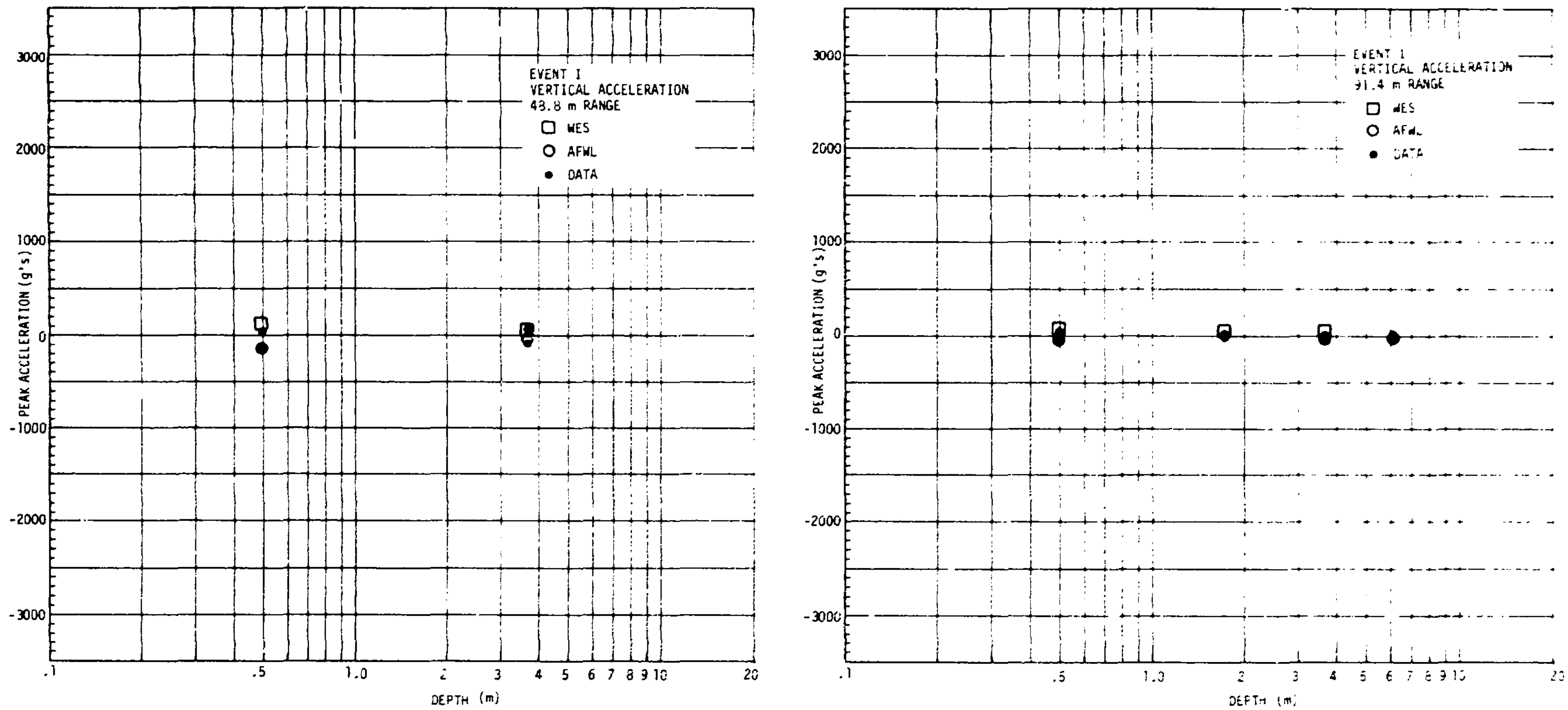


Figure 4.9. Vertical Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 1

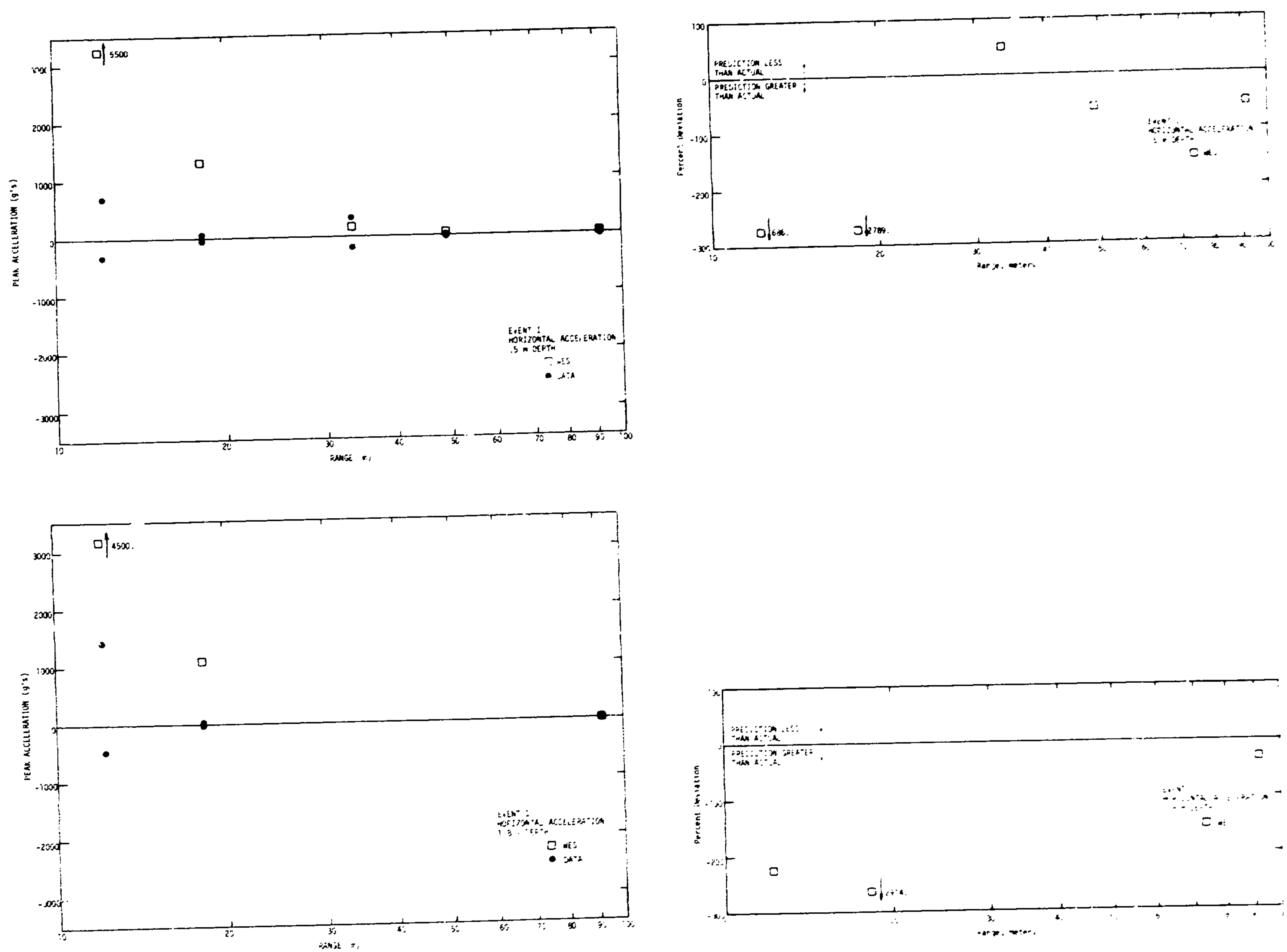


Figure 4.10. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

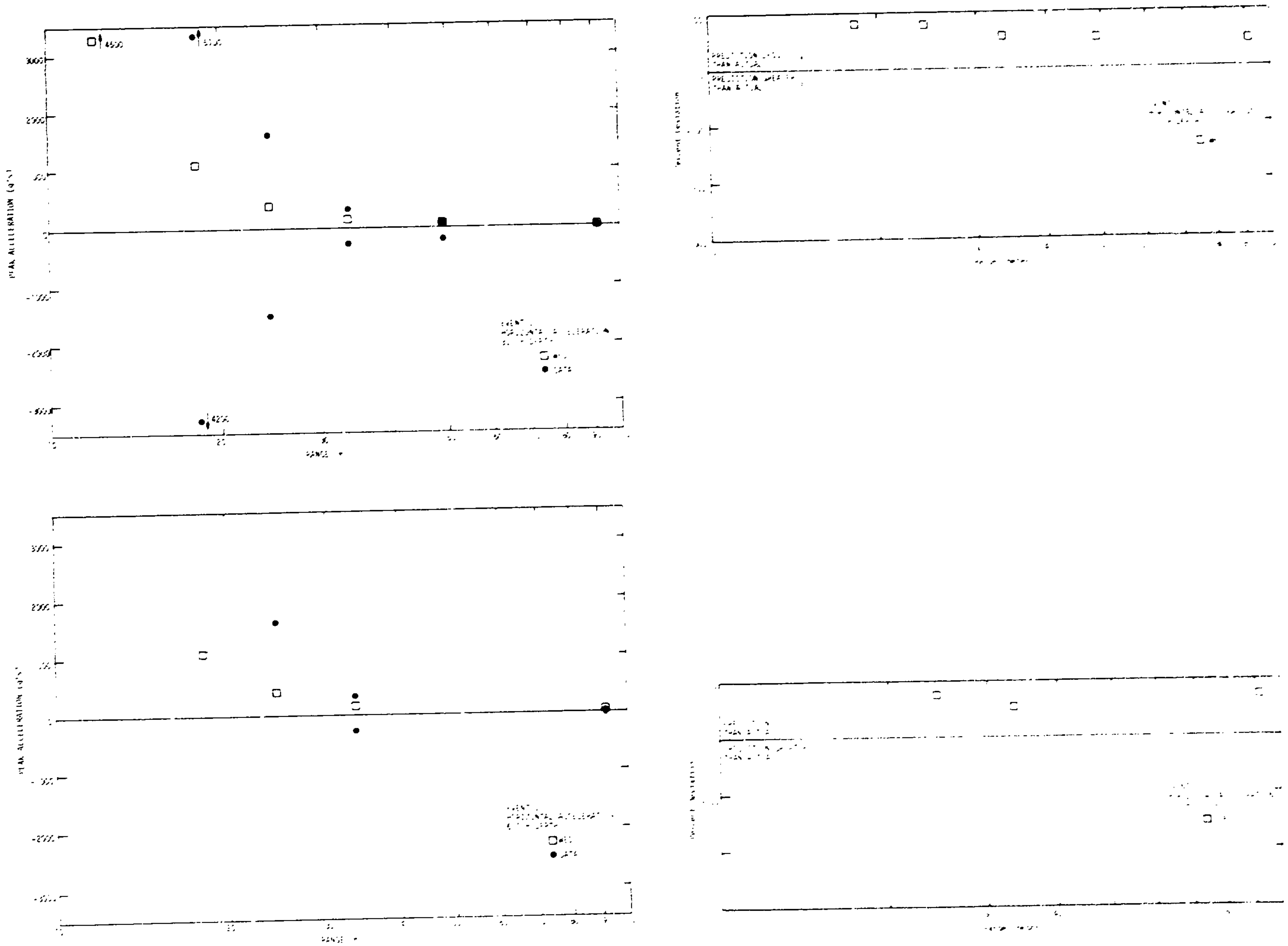


Figure 4.11. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

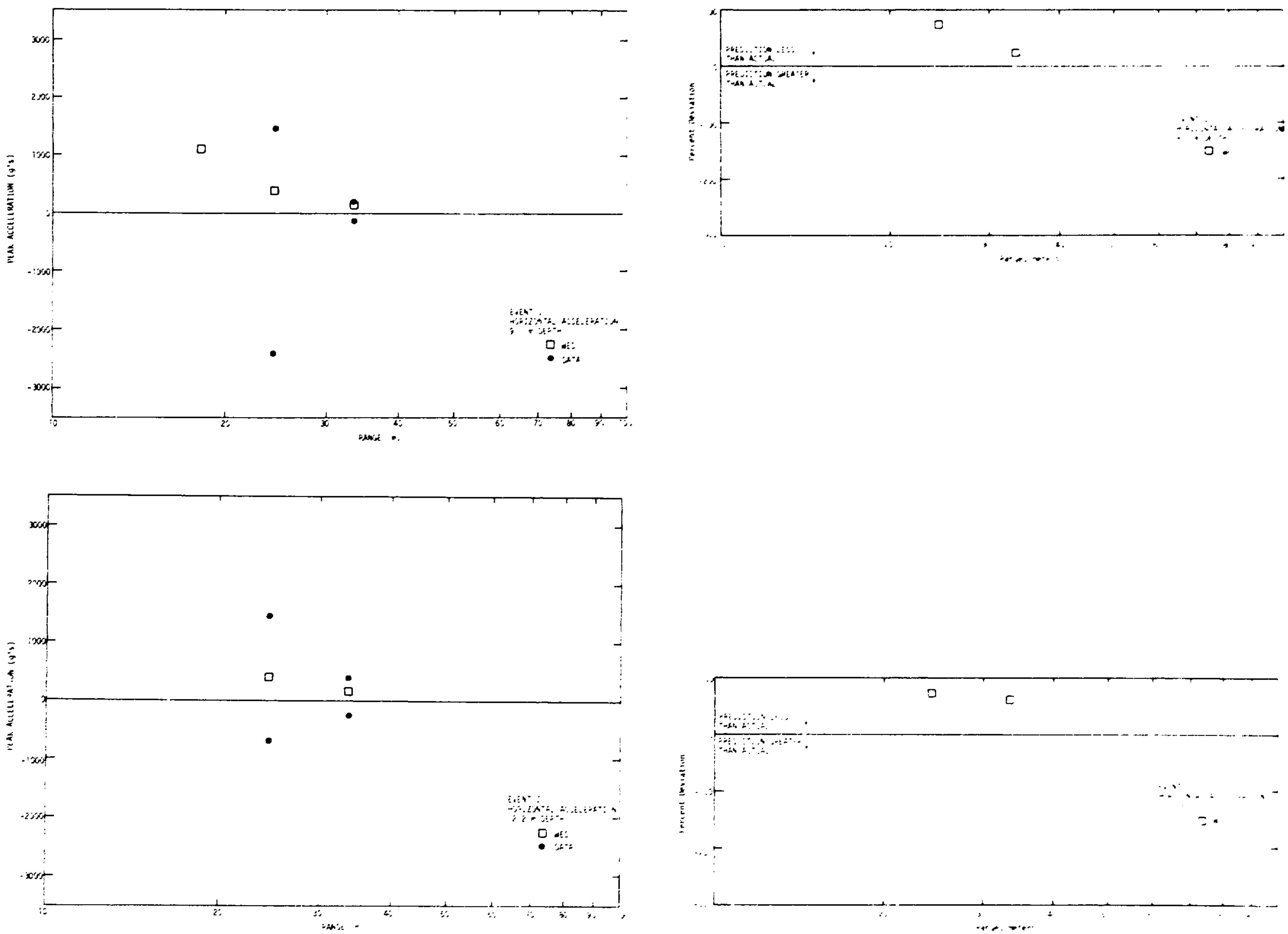


Figure 4.12. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

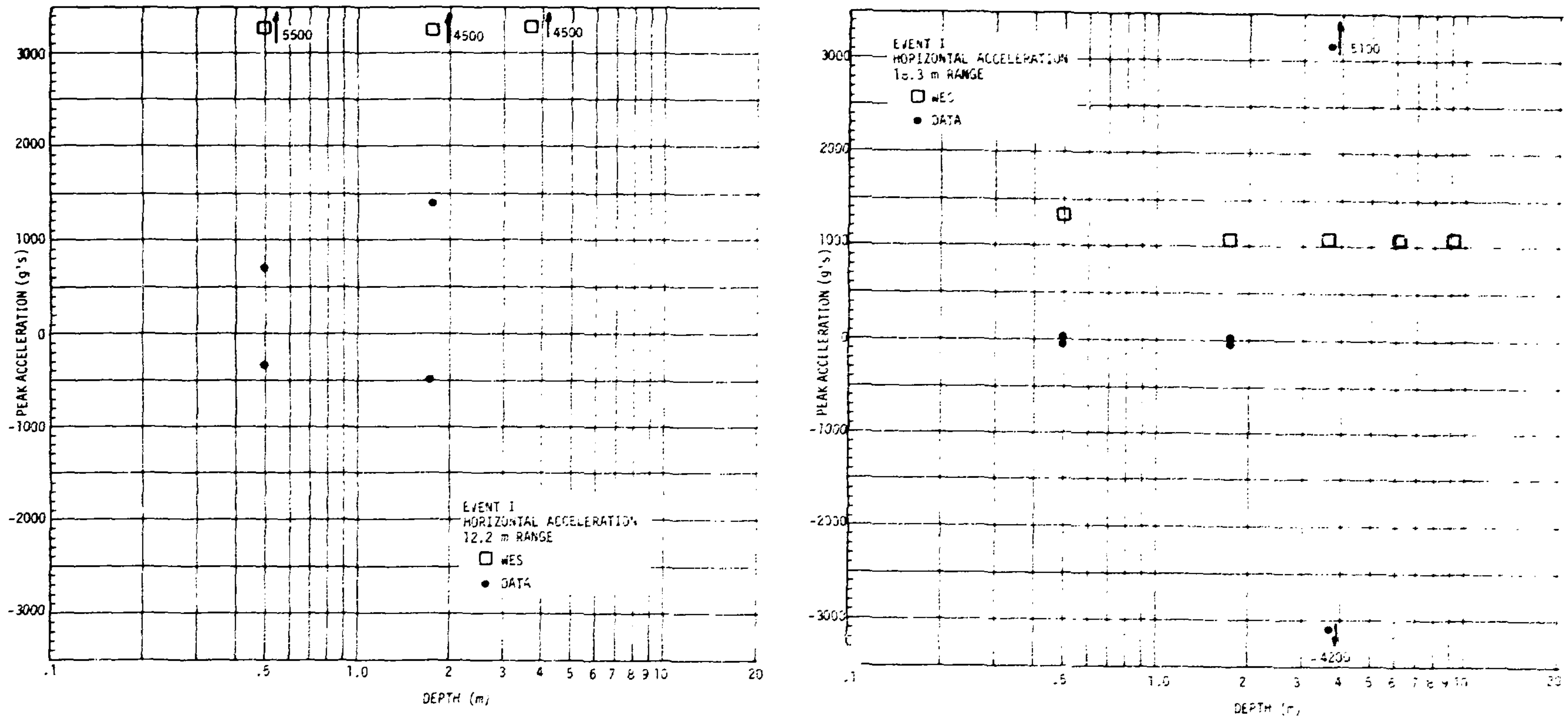
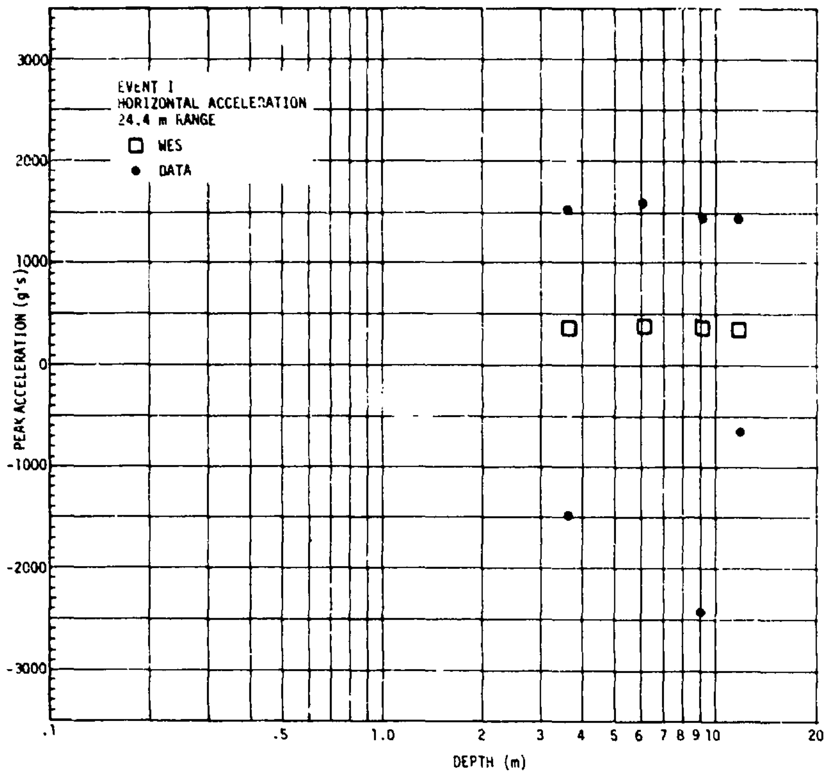


Figure 4.13. Horizontal Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event I



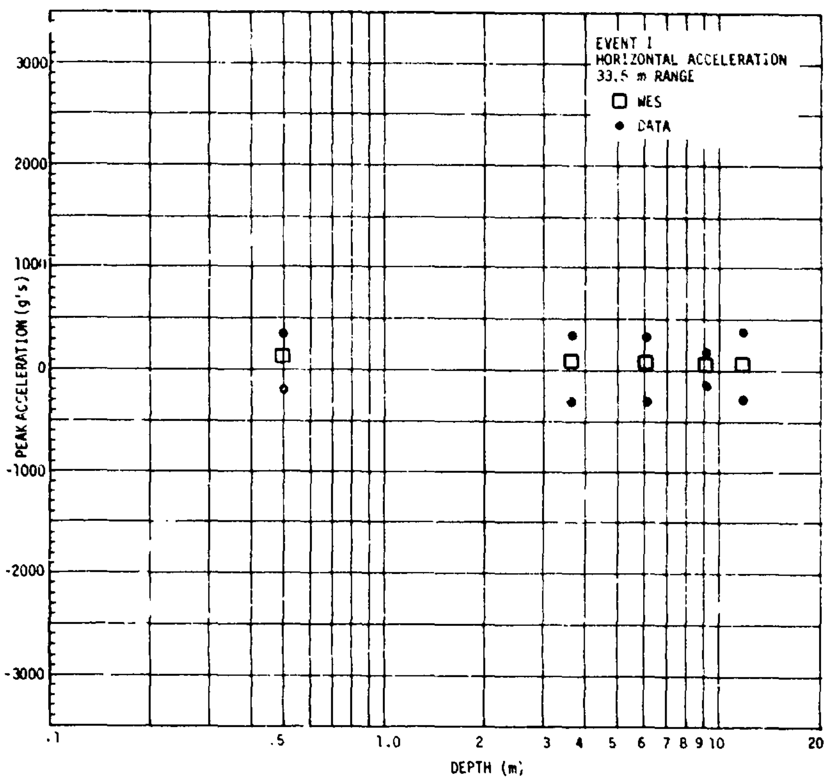


Figure 4.14. Horizontal Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 1

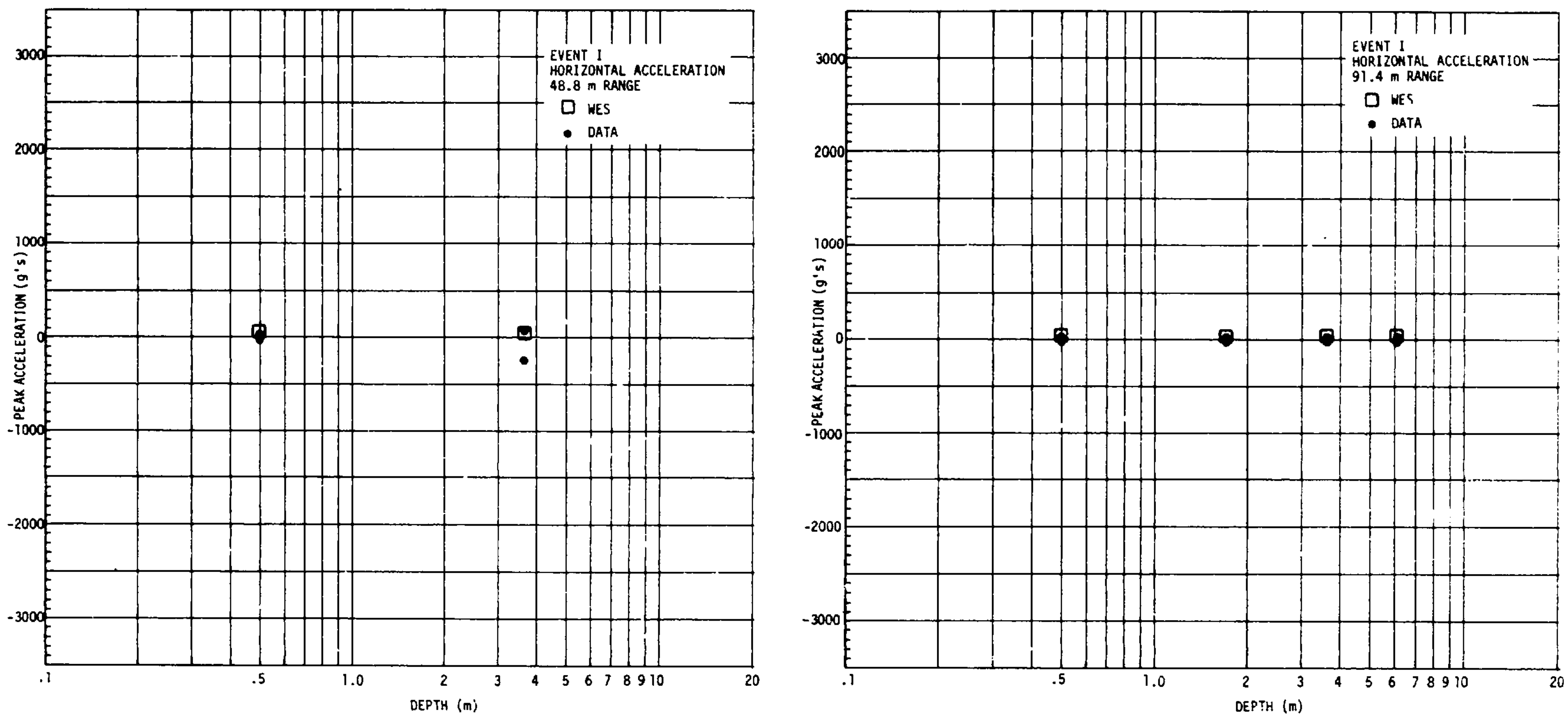
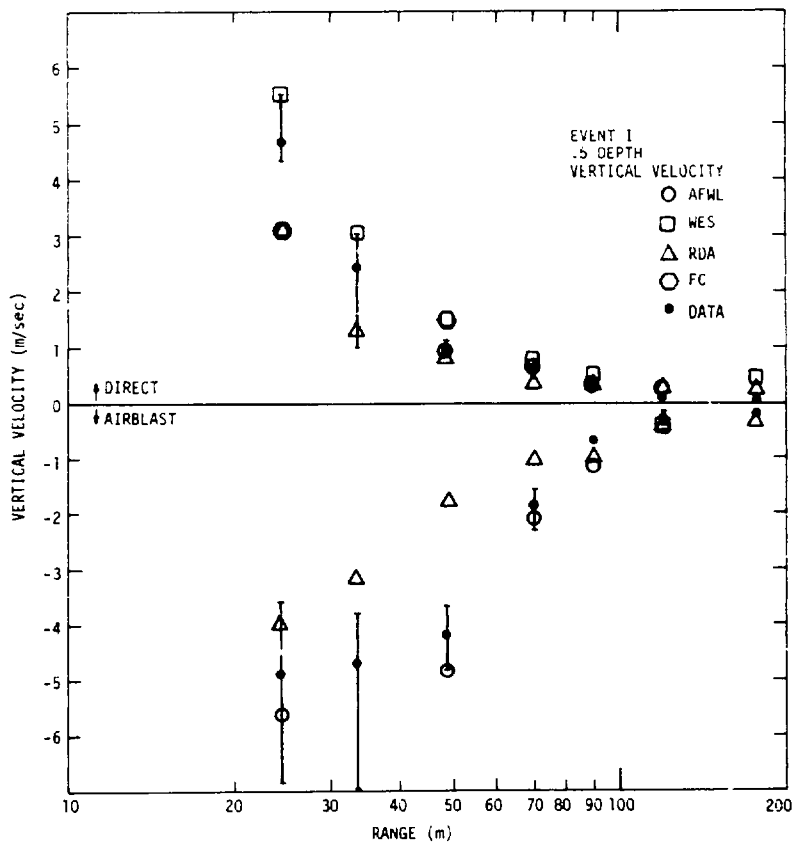
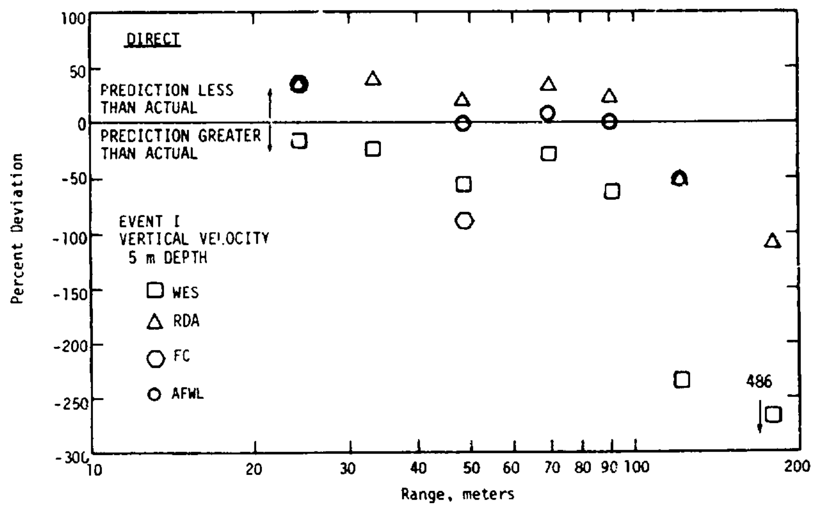


Figure 4.15. Horizontal Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 1





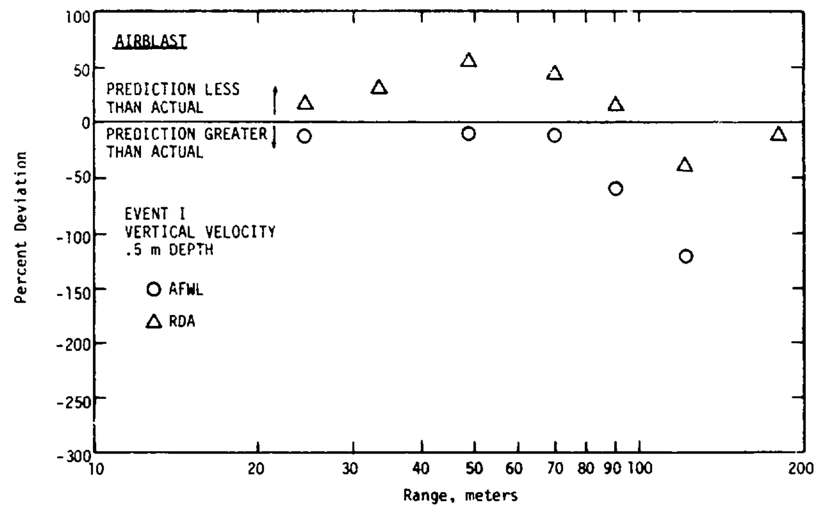


Figure 4.16. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

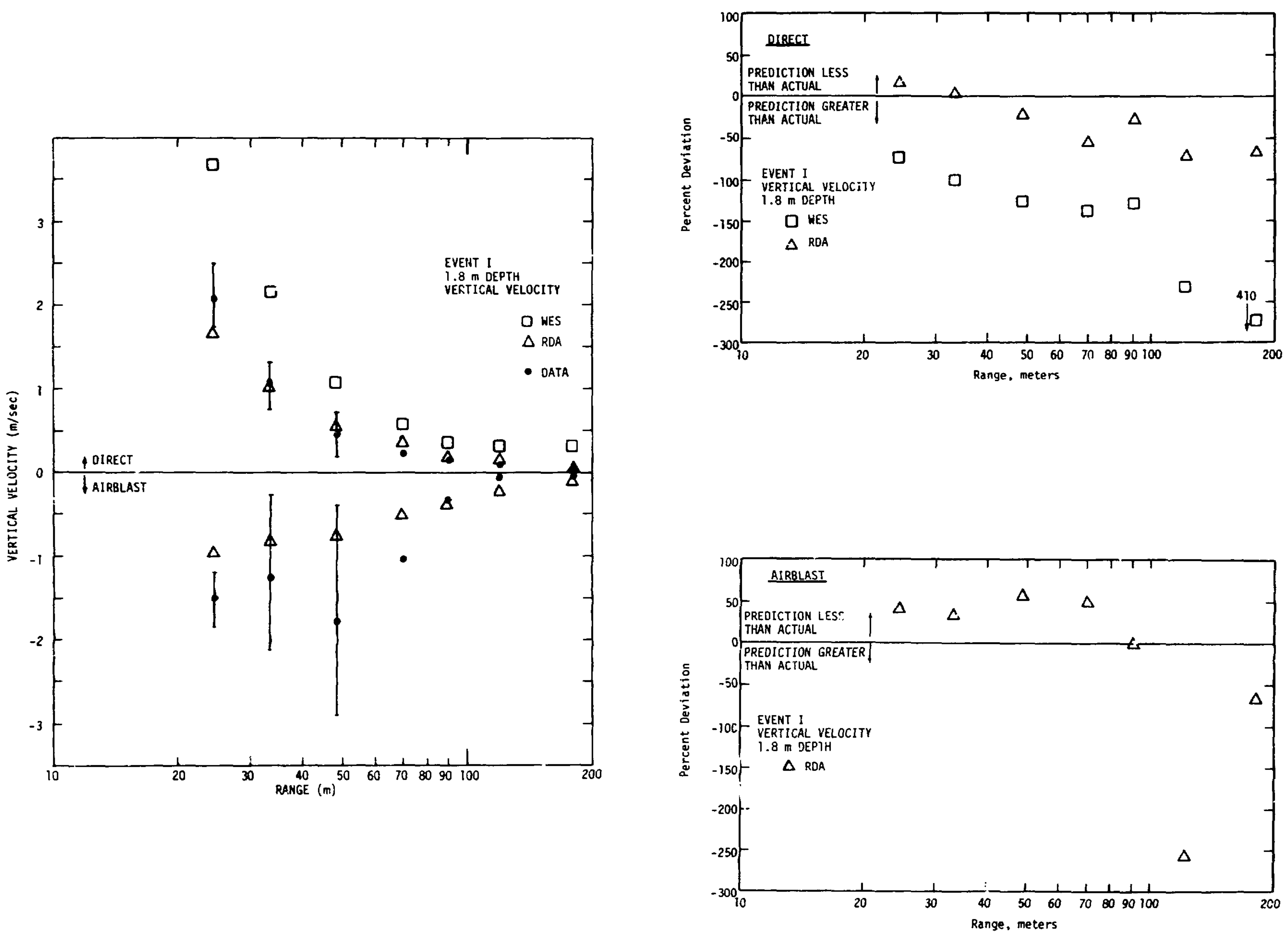
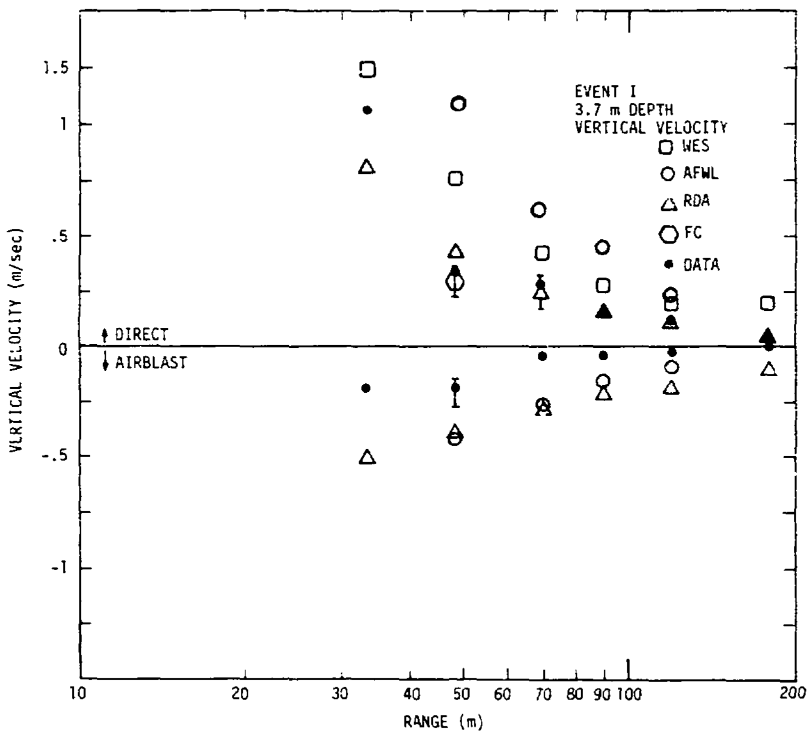
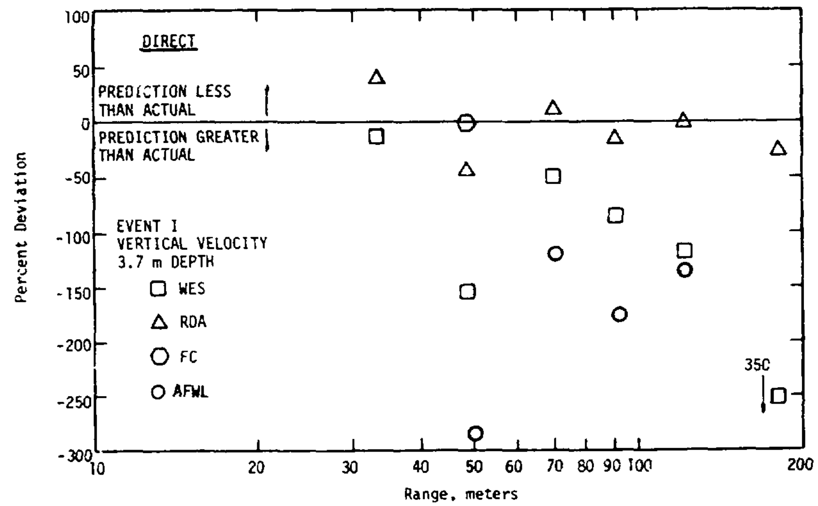


Figure 4.17. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1





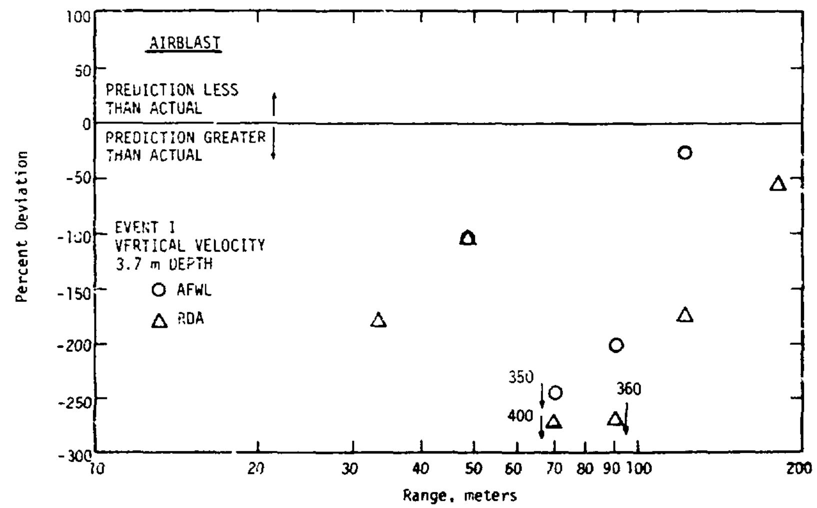


Figure 4.18. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

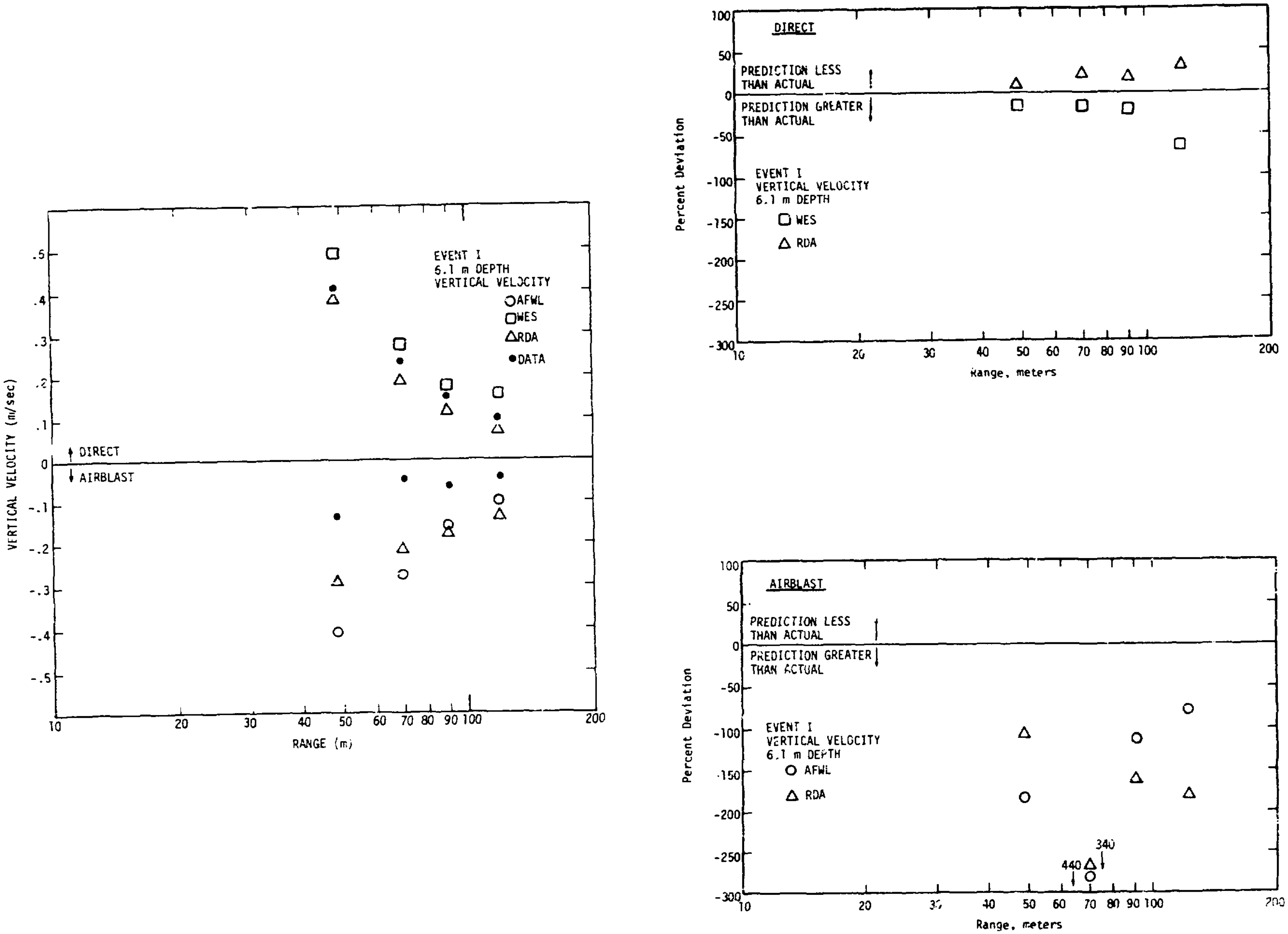


Figure 4.19. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

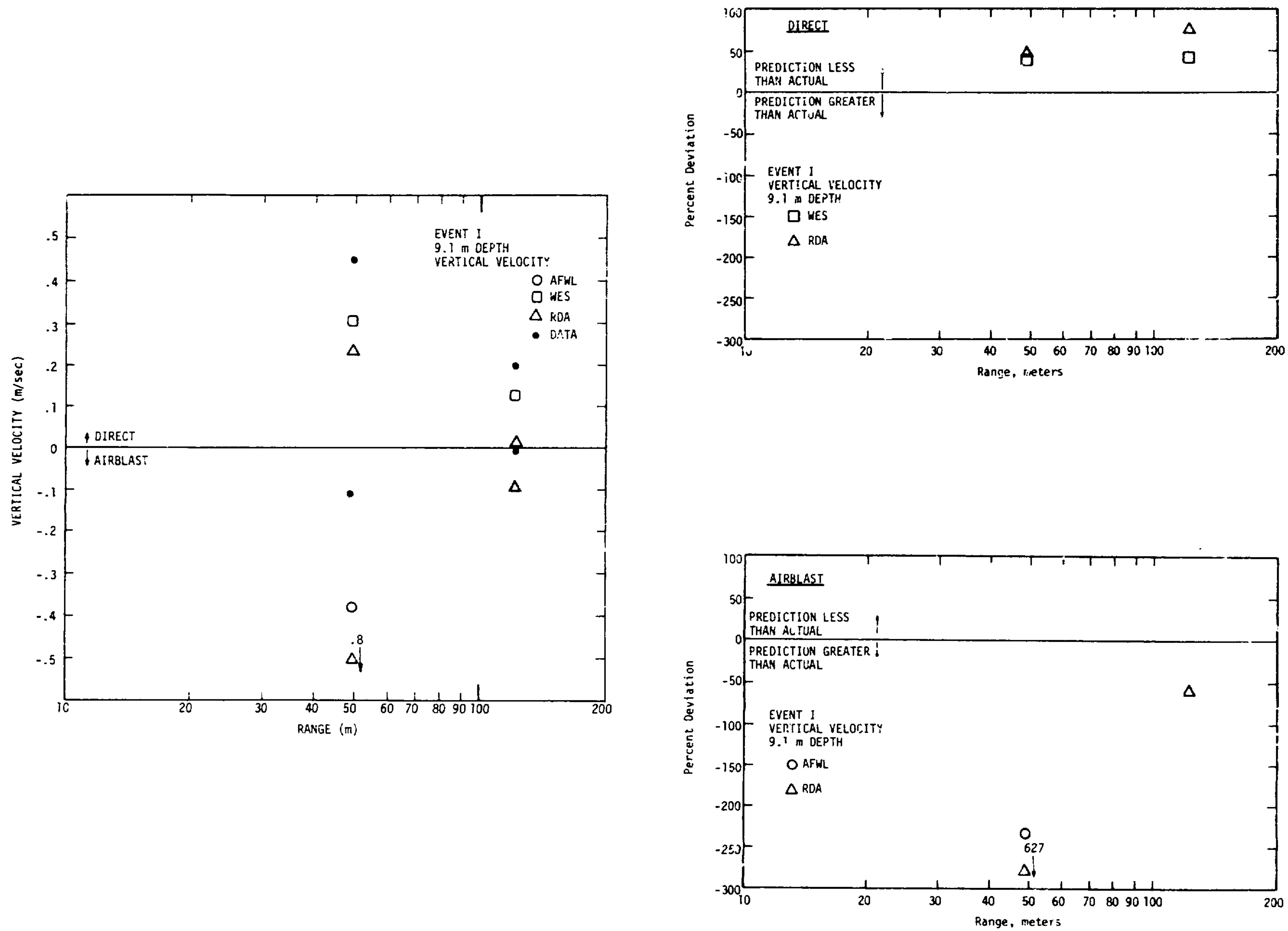


Figure 4.20. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

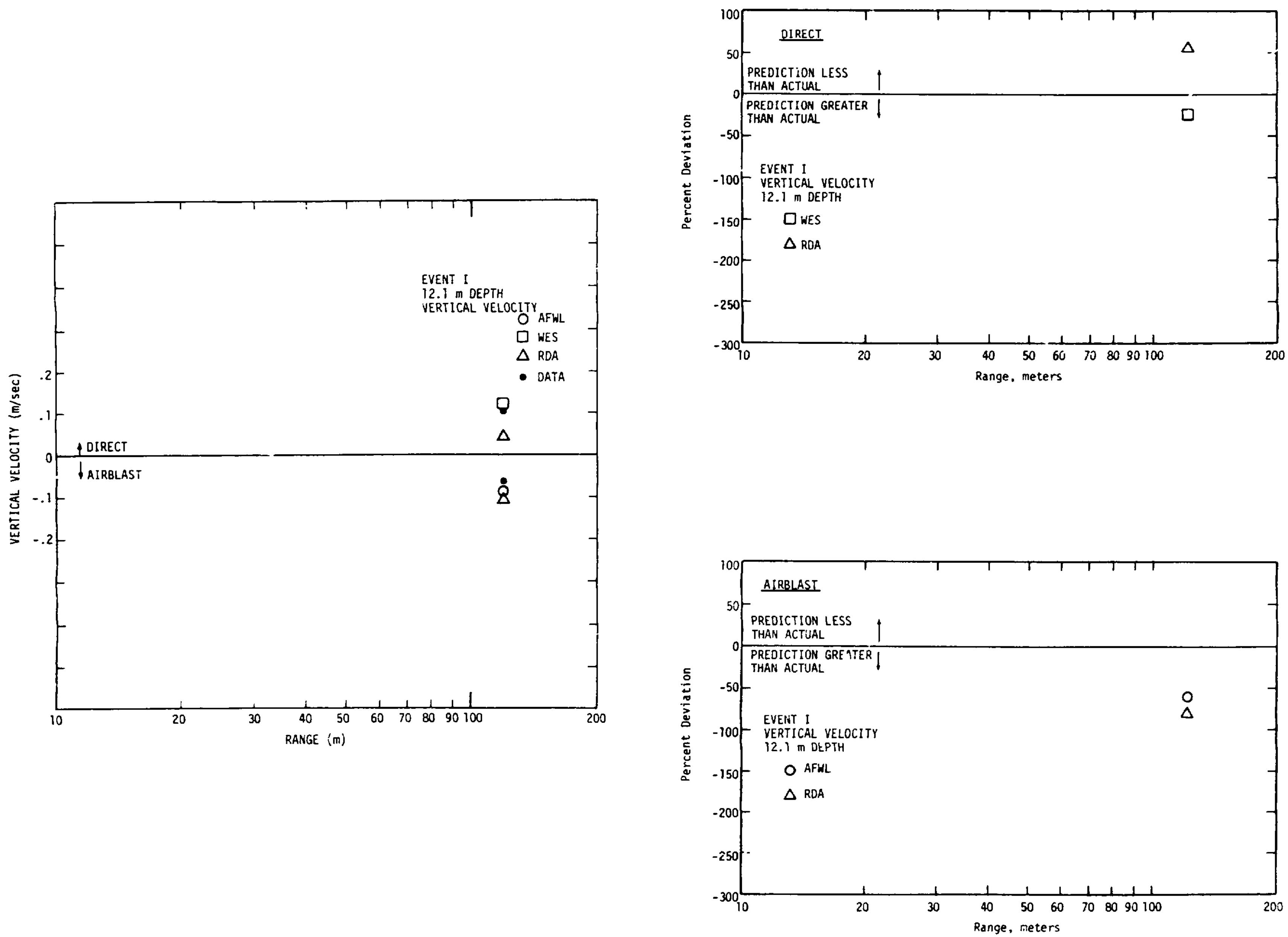


Figure 4.21. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event I

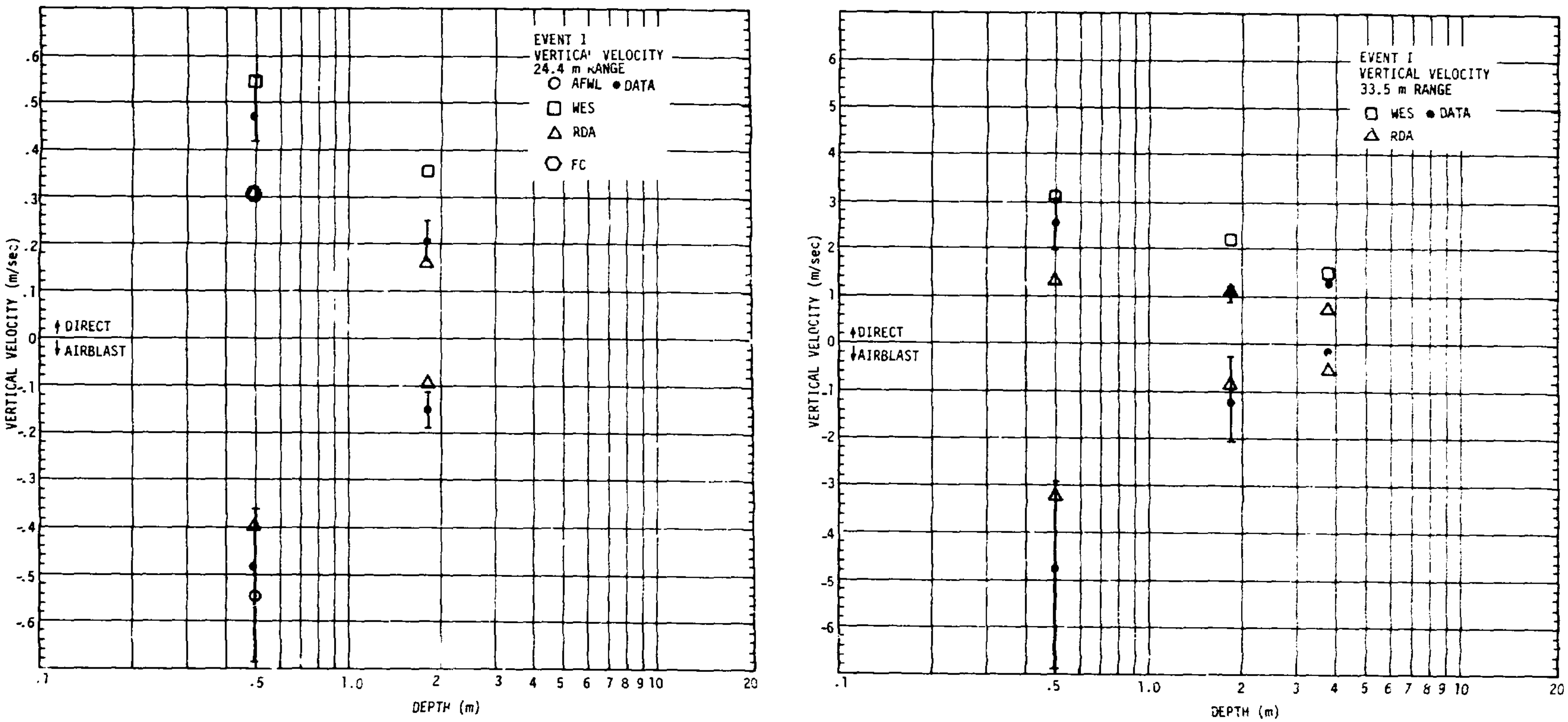


Figure 4.22. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

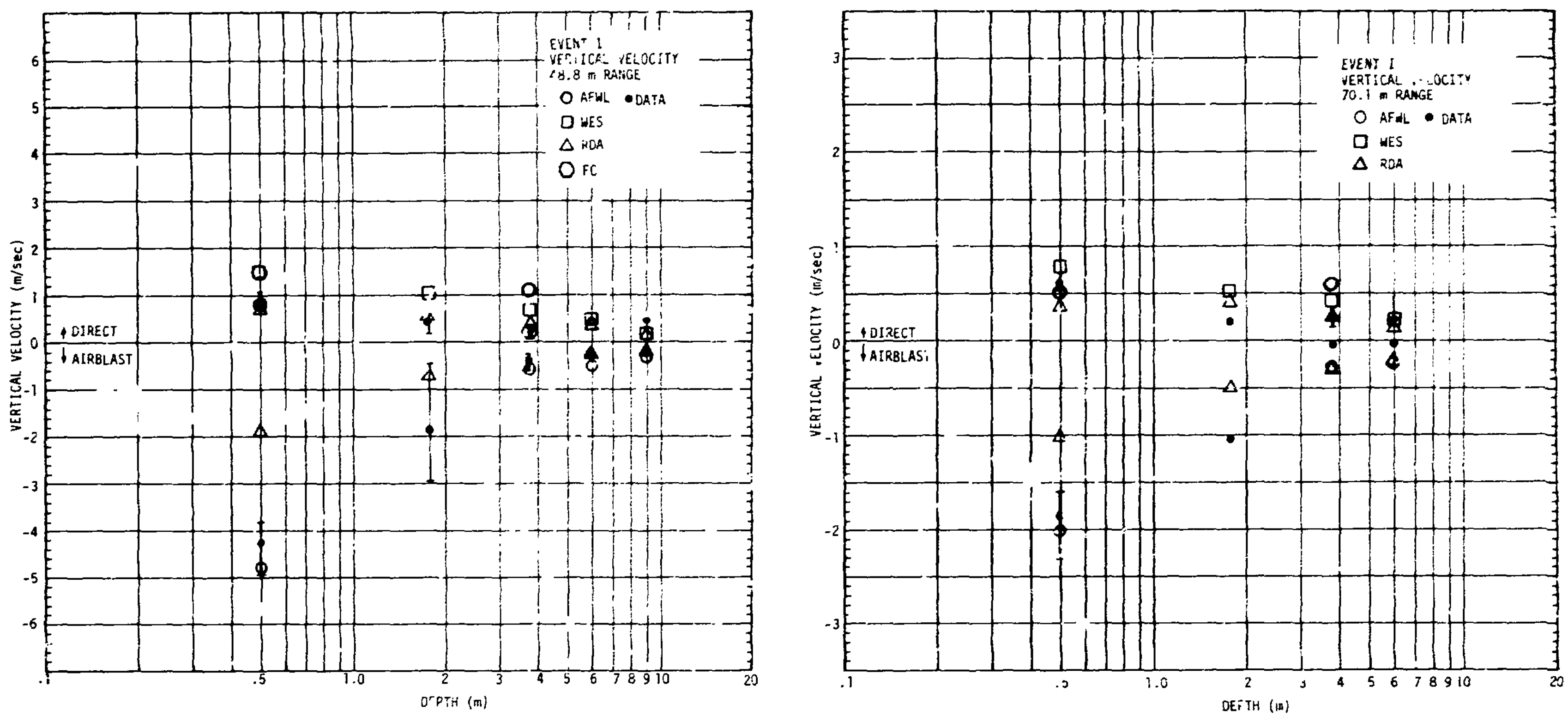


Figure 4.23. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

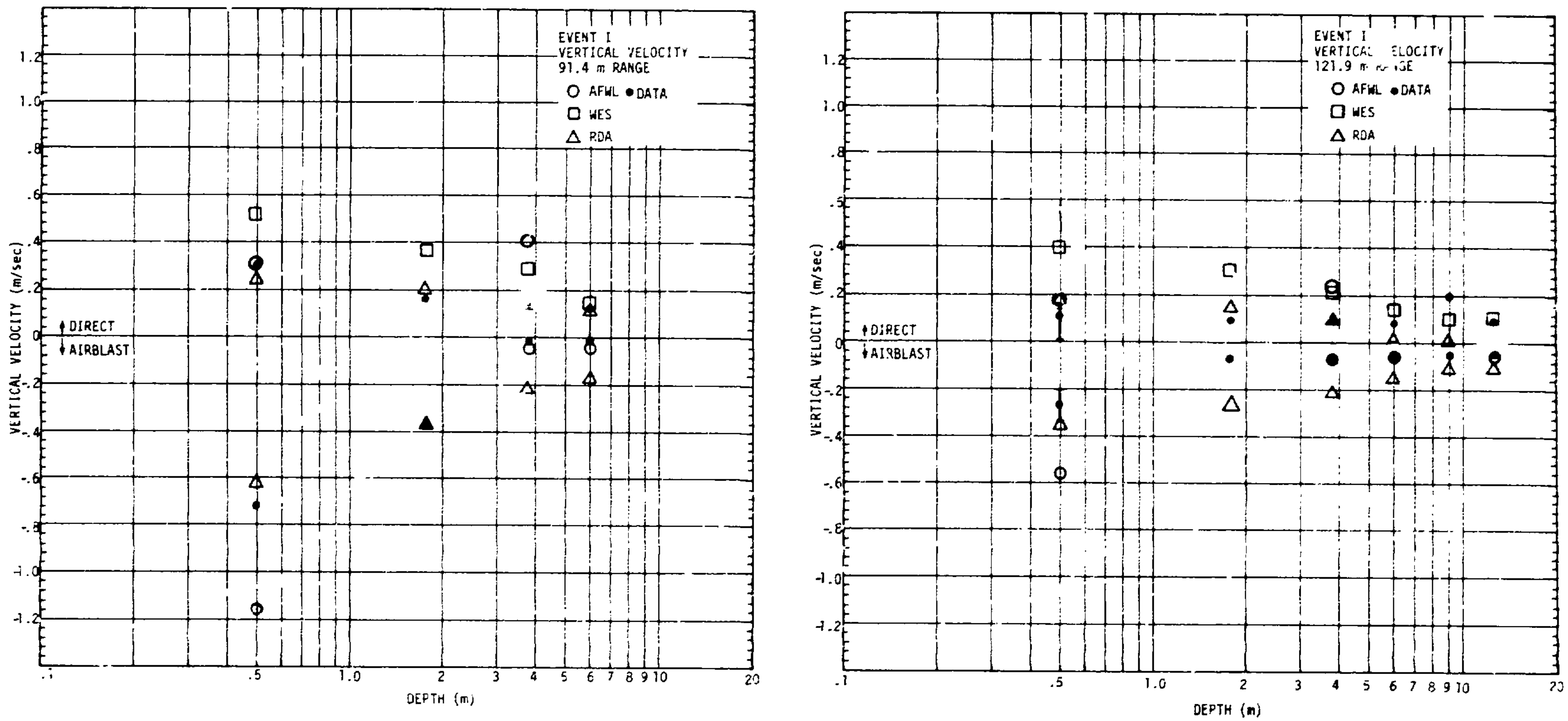


Figure 4.24. Vertical Velocity vs. Depth with Predictions for . ɜ-DICE THROW II, Event 1

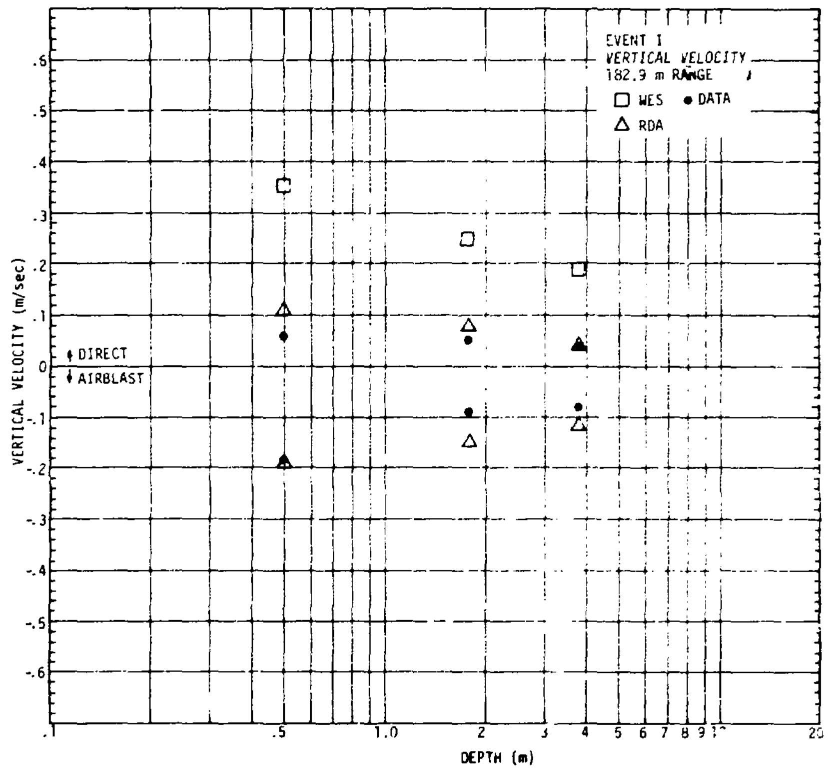


Figure 4.25. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

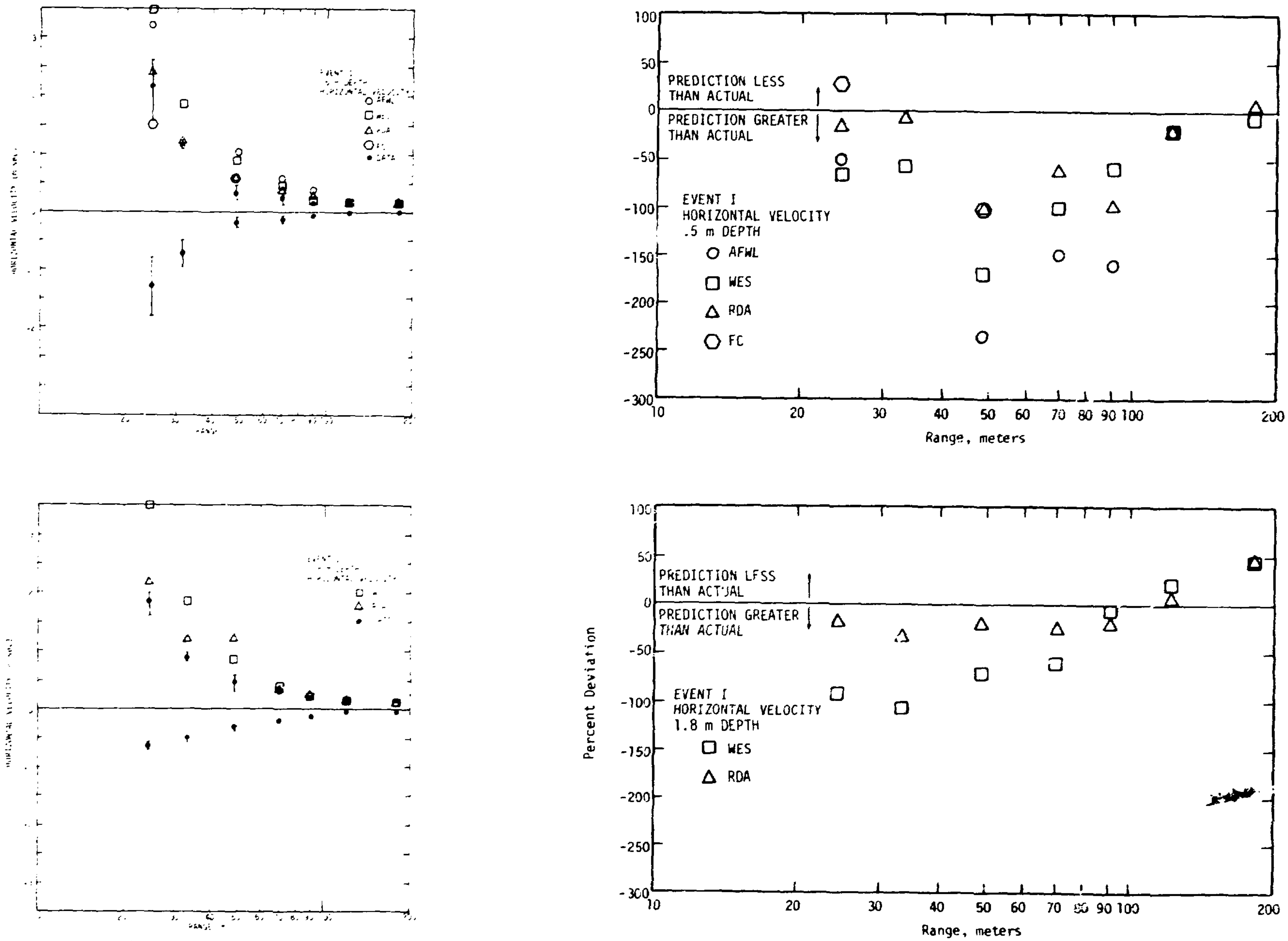


Figure 4.26. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

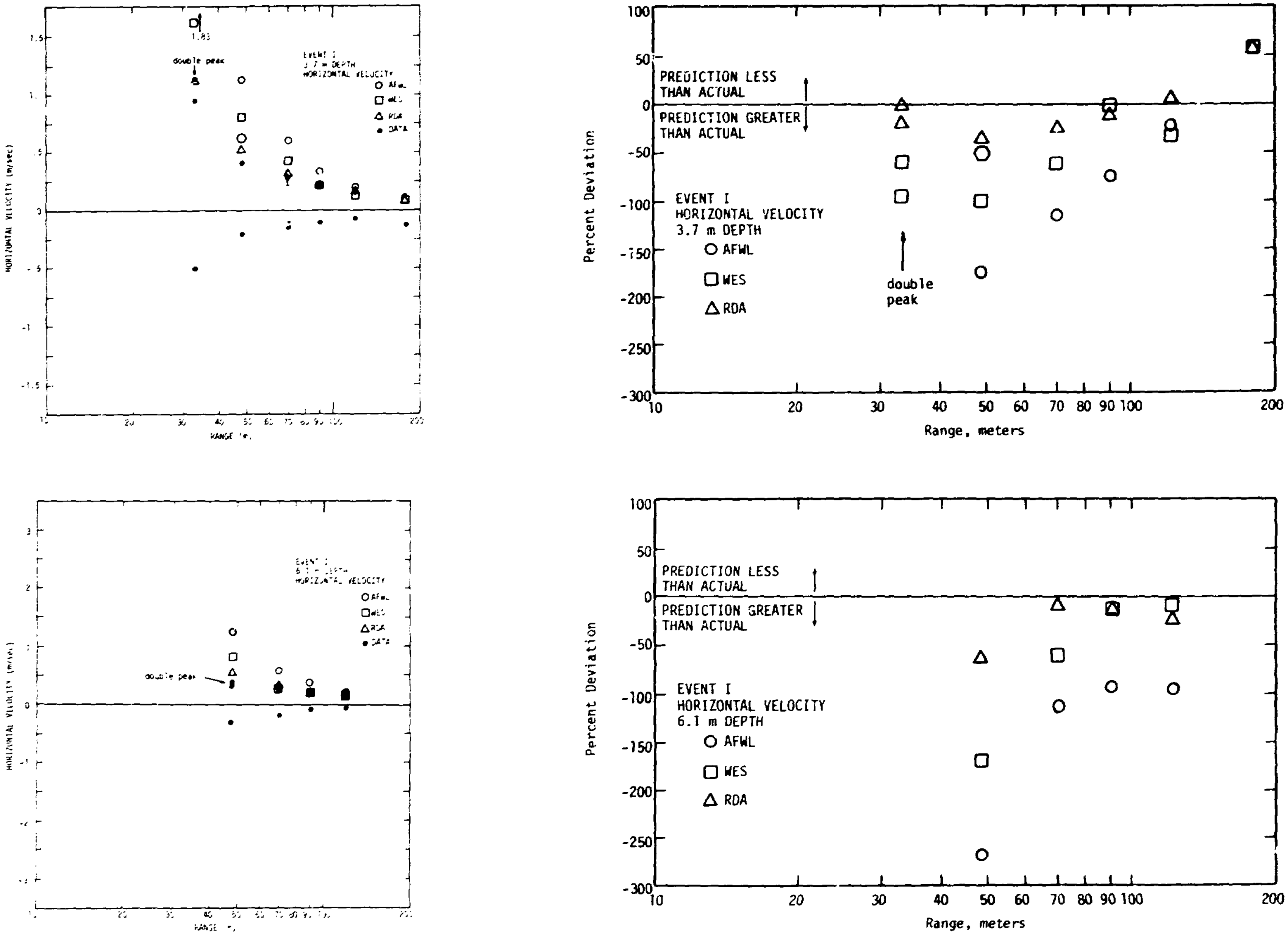


Figure 4.27. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

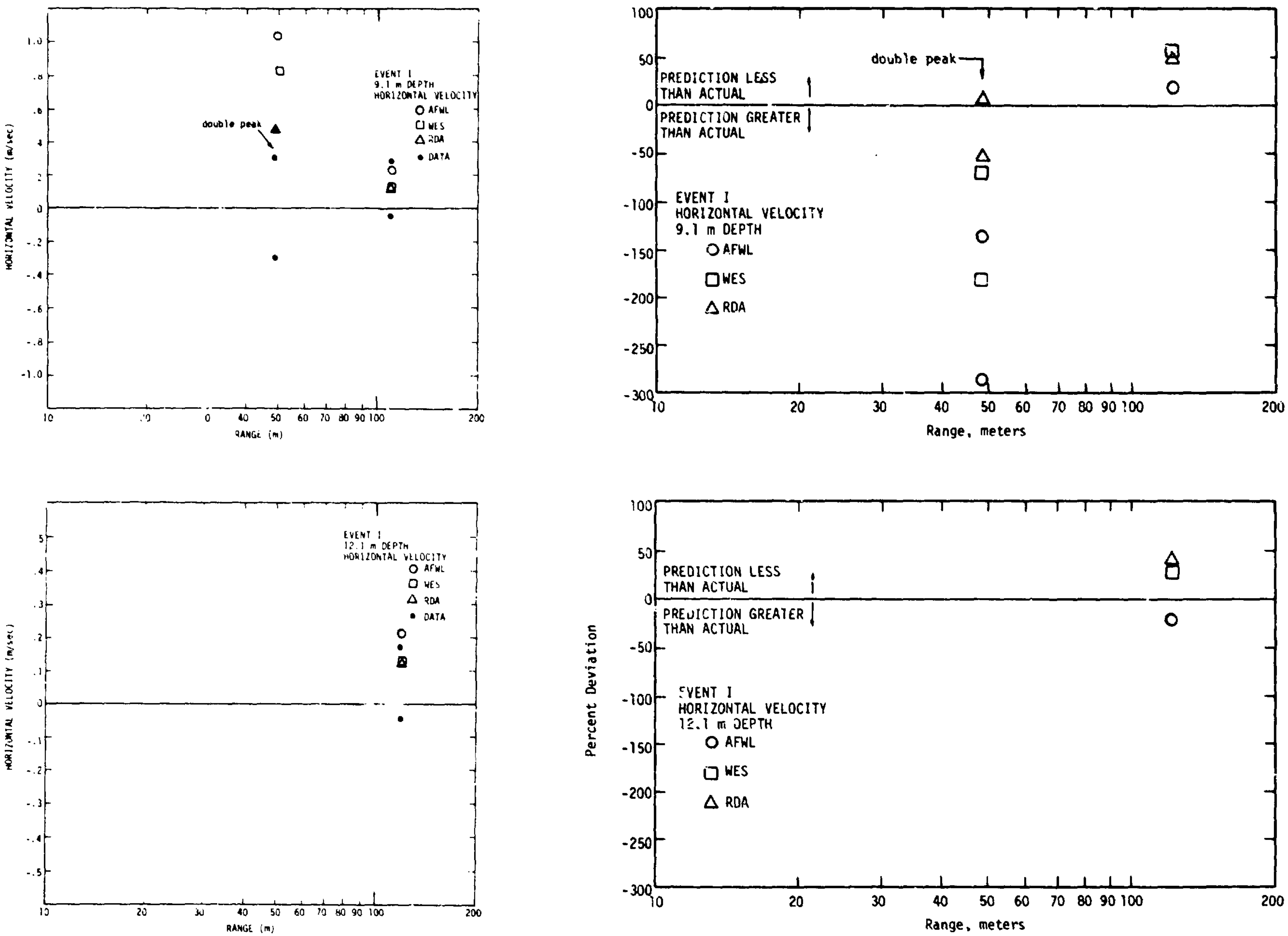


Figure 4.28. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

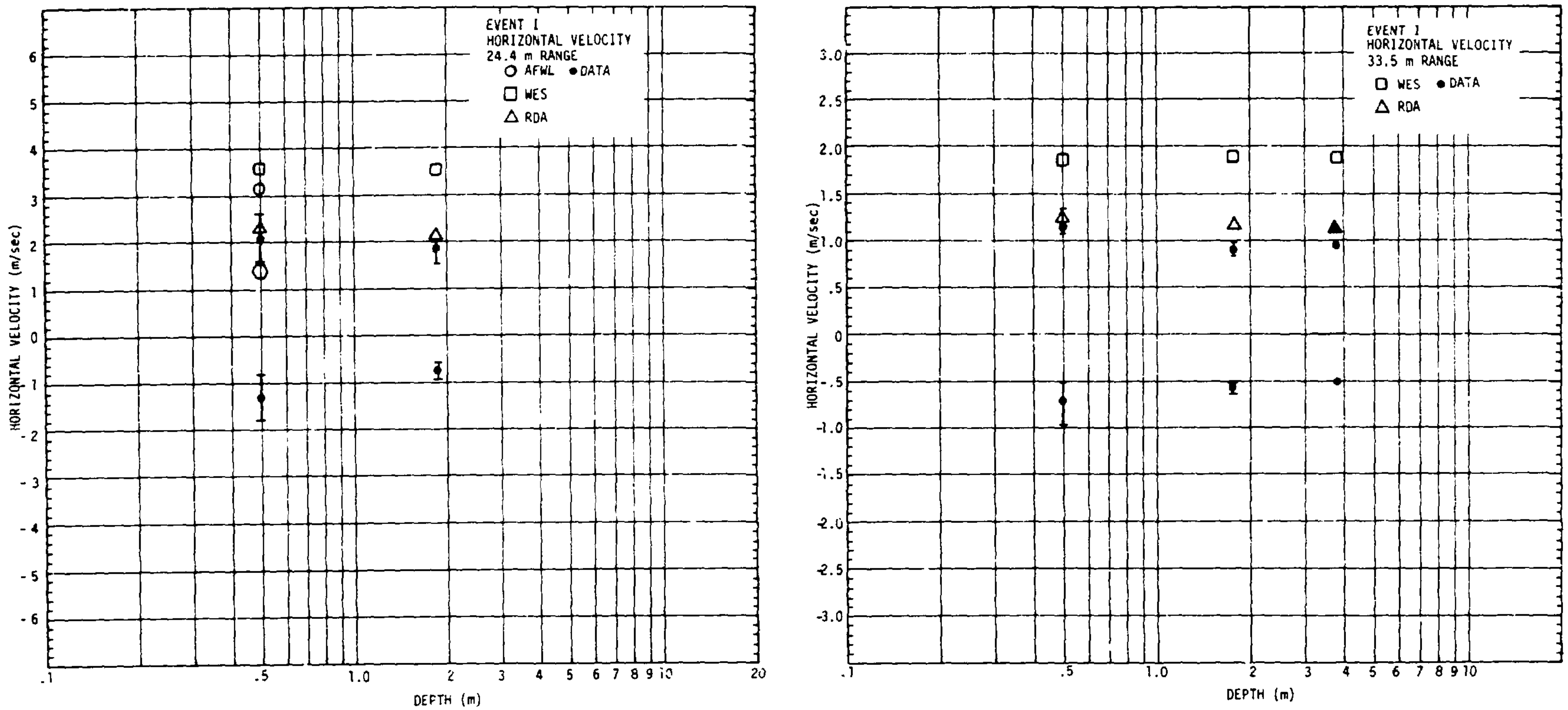


Figure 4.29. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

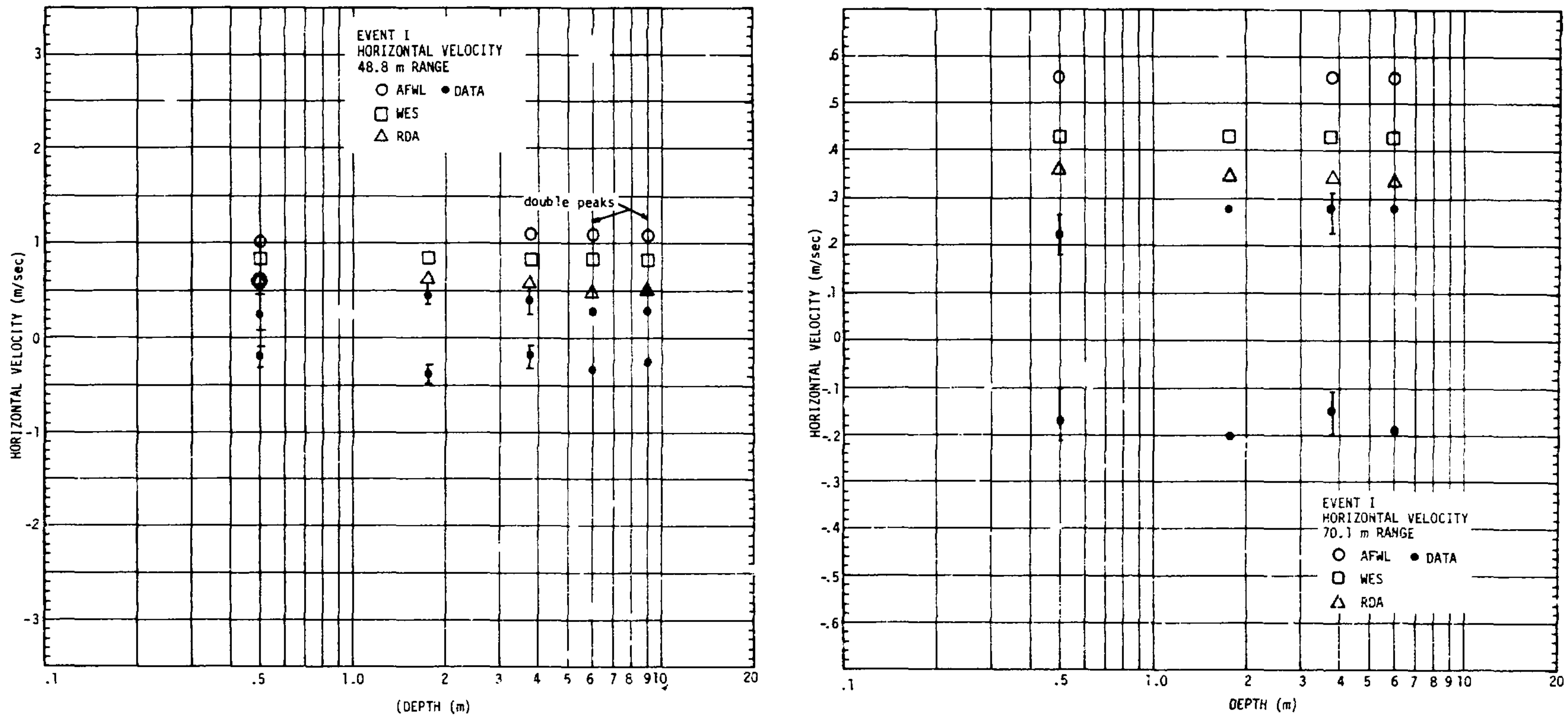


Figure 4.30. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

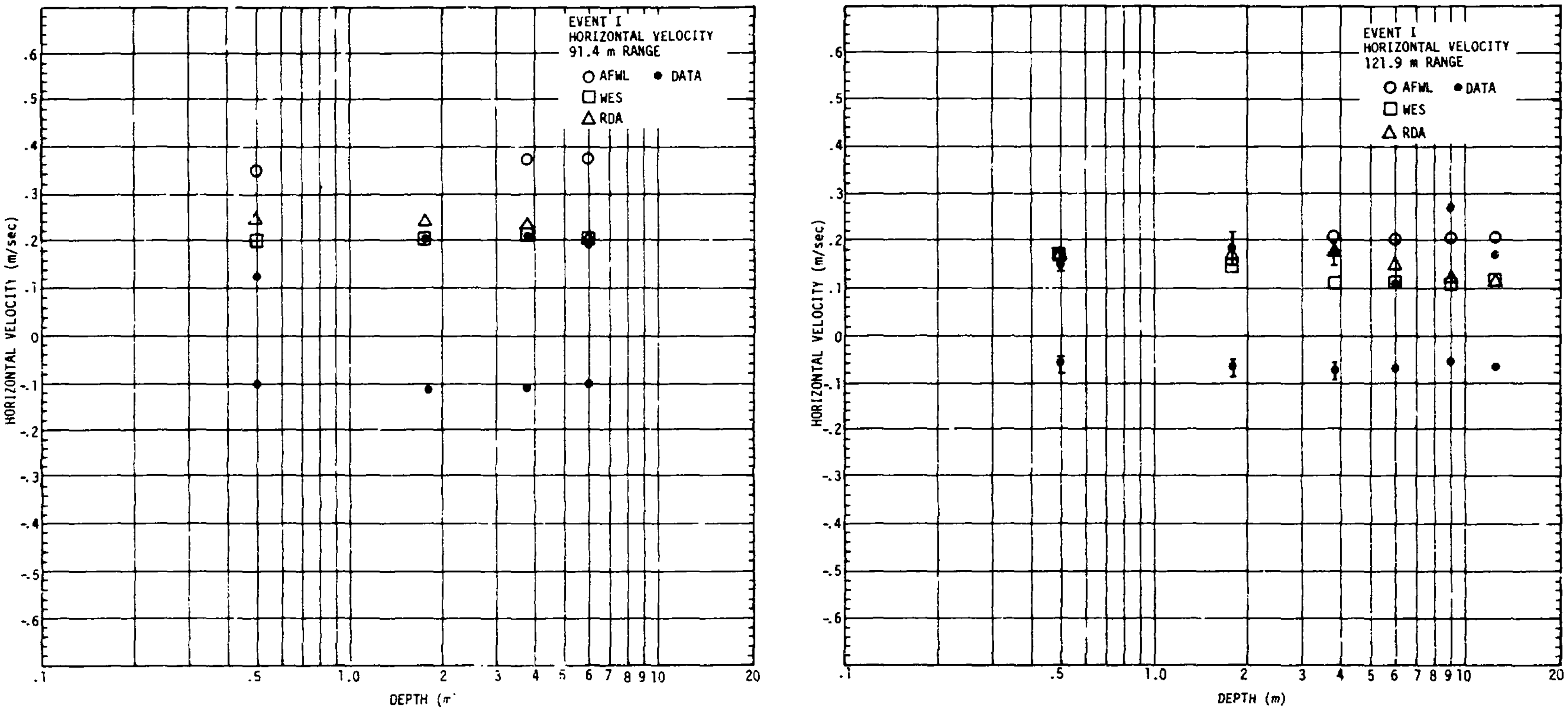


Figure 4.31. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

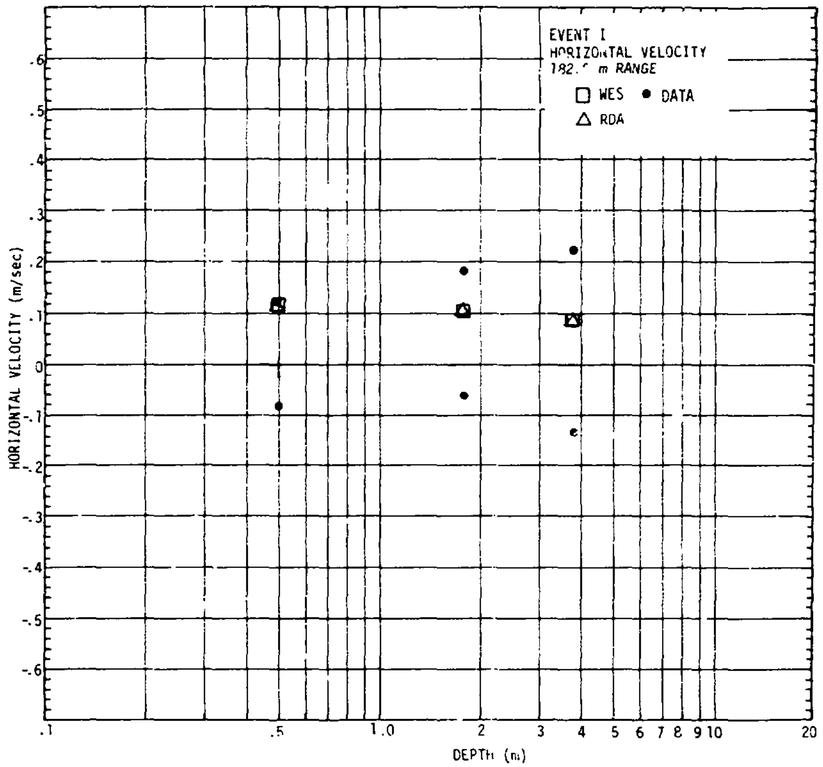


Figure 4.32. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 1

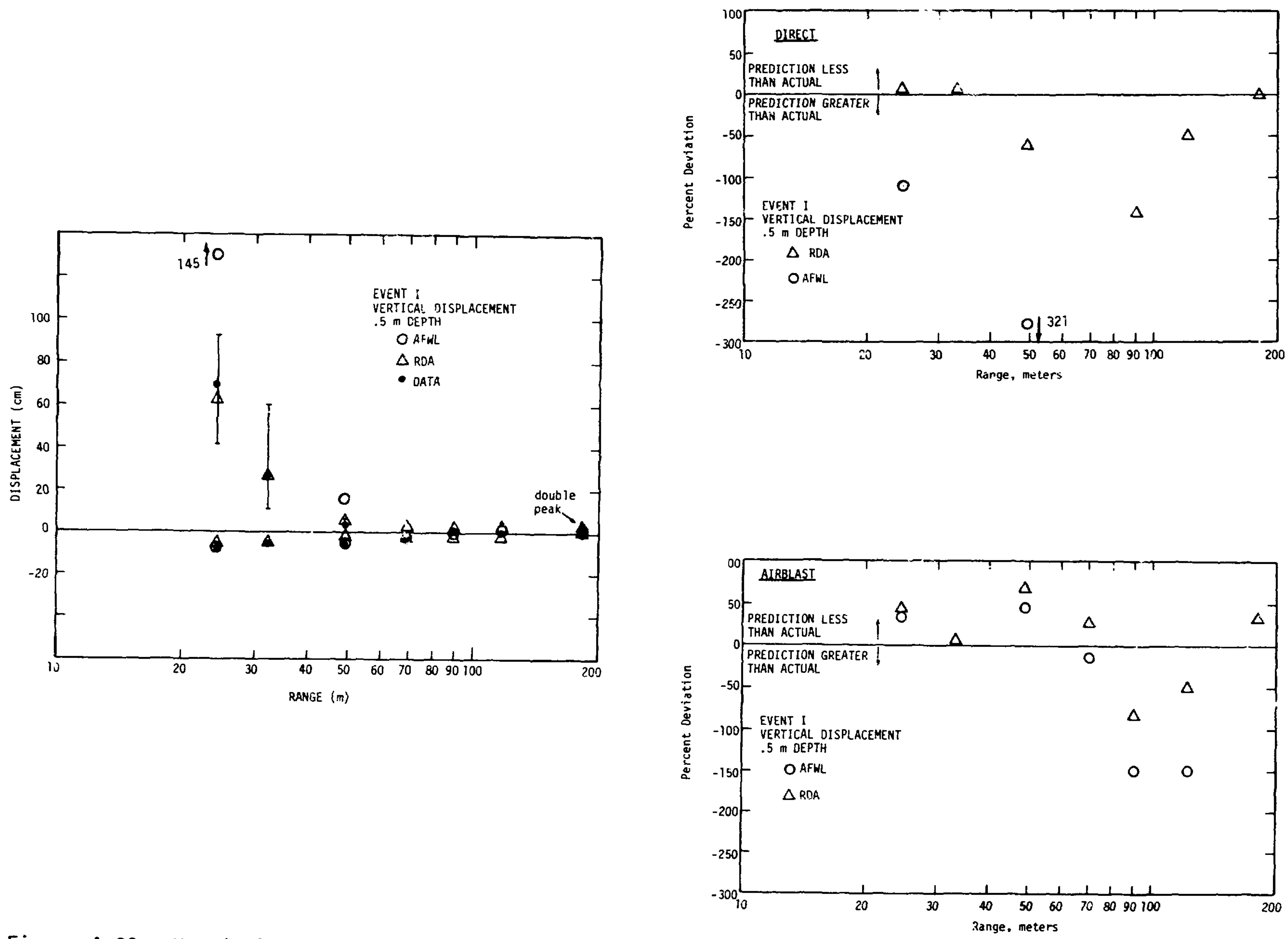


Figure 4.33. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

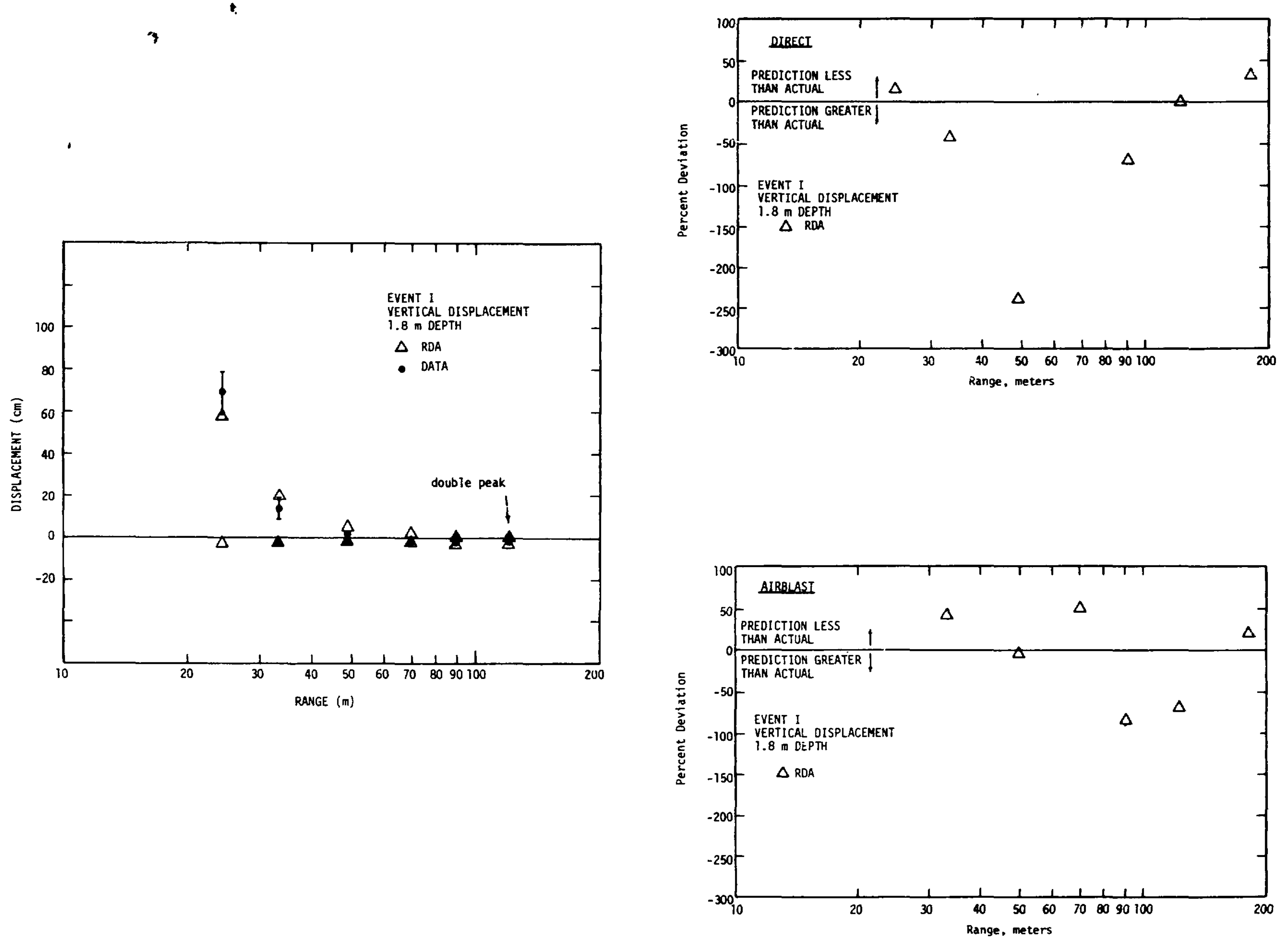


Figure 4.34. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

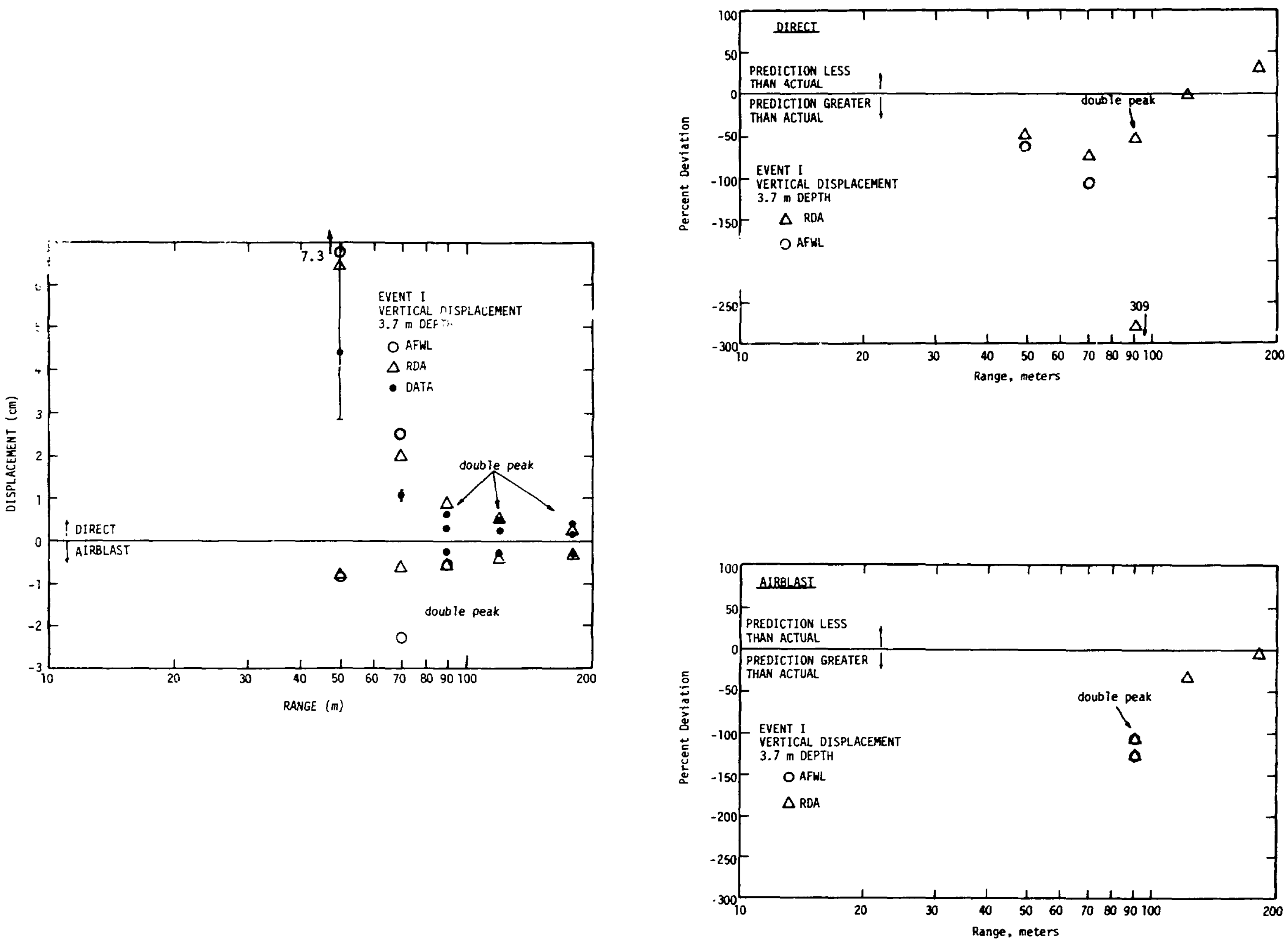


Figure 4.35. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

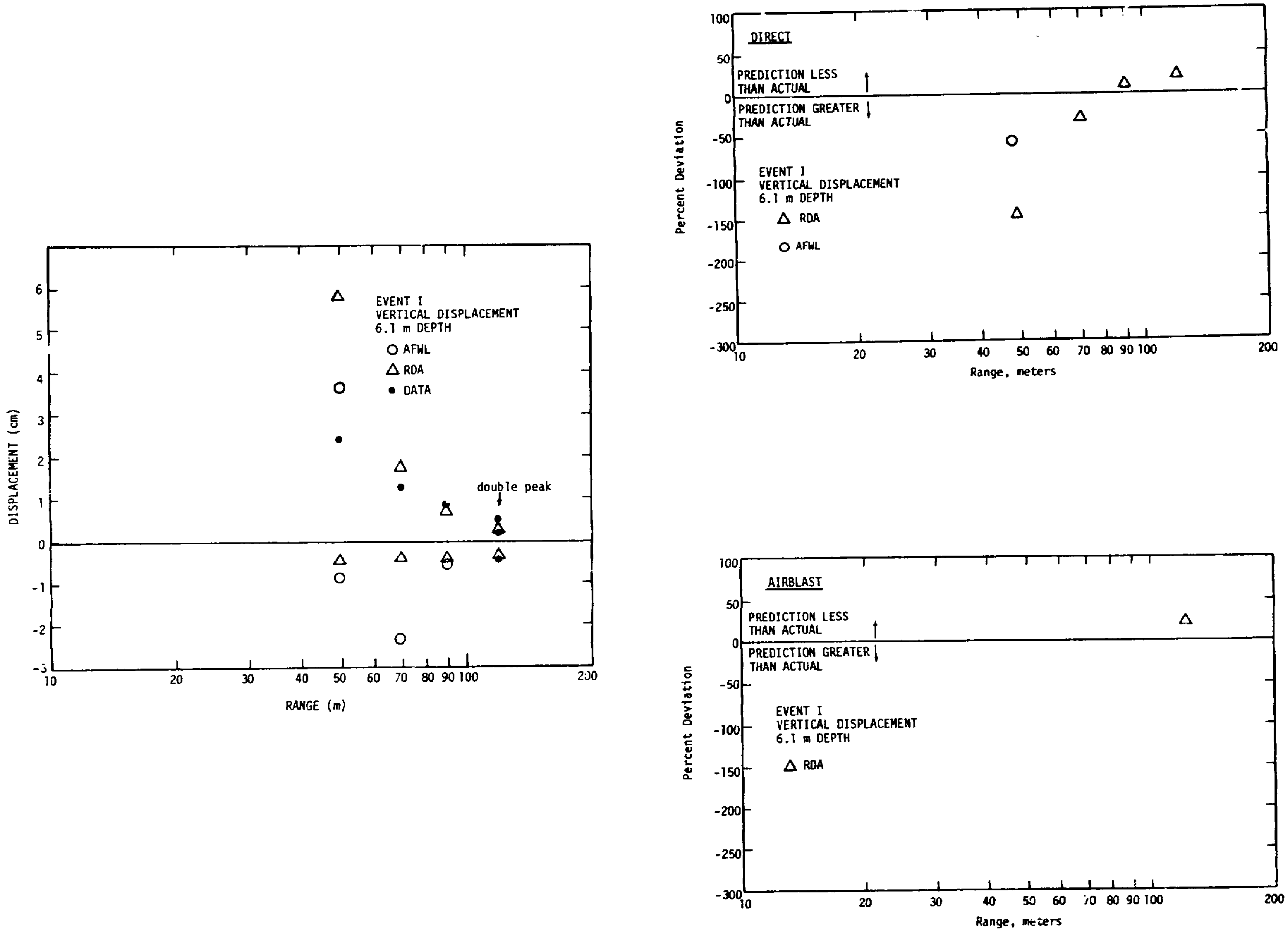


Figure 4.36. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event I

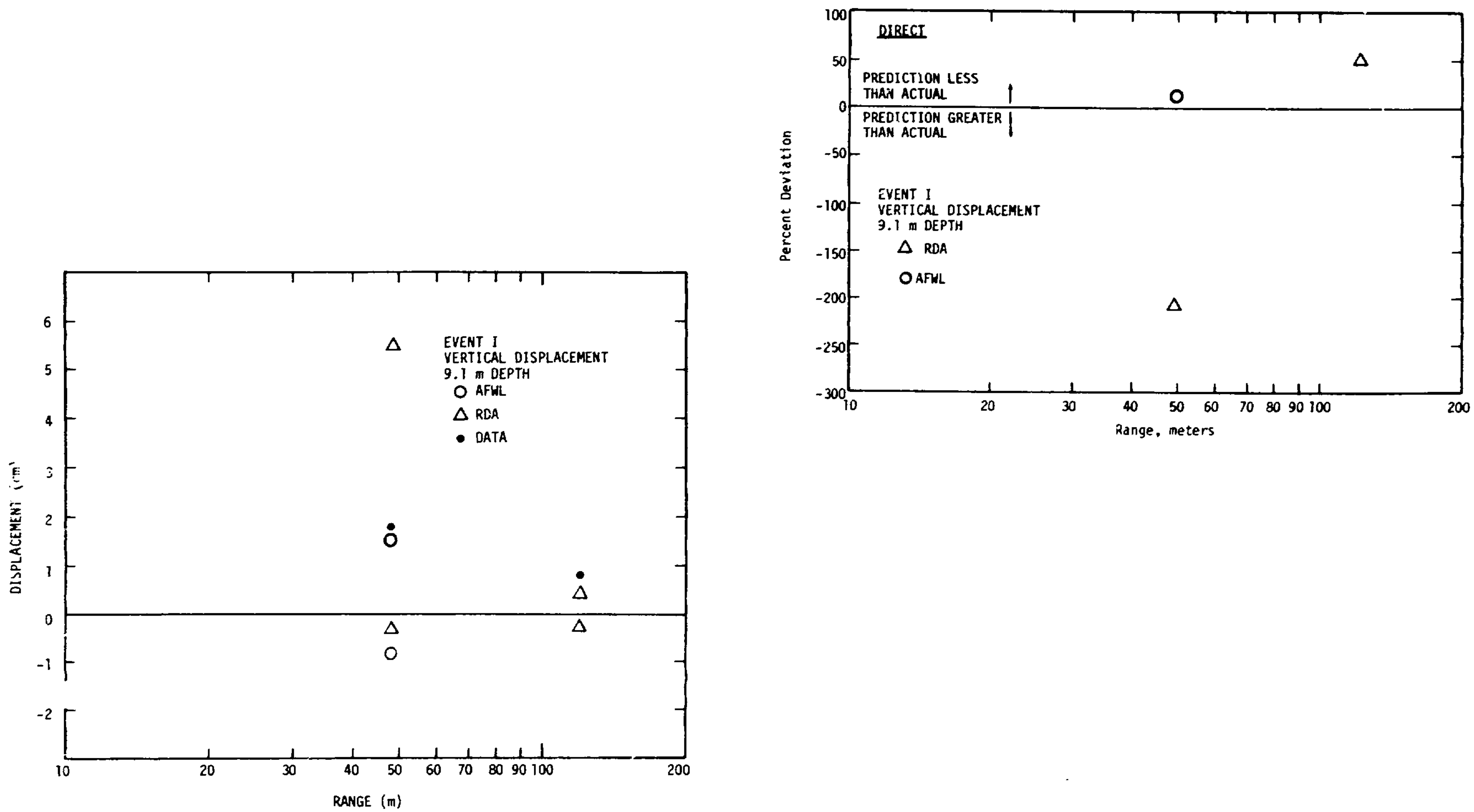


Figure 4.37. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

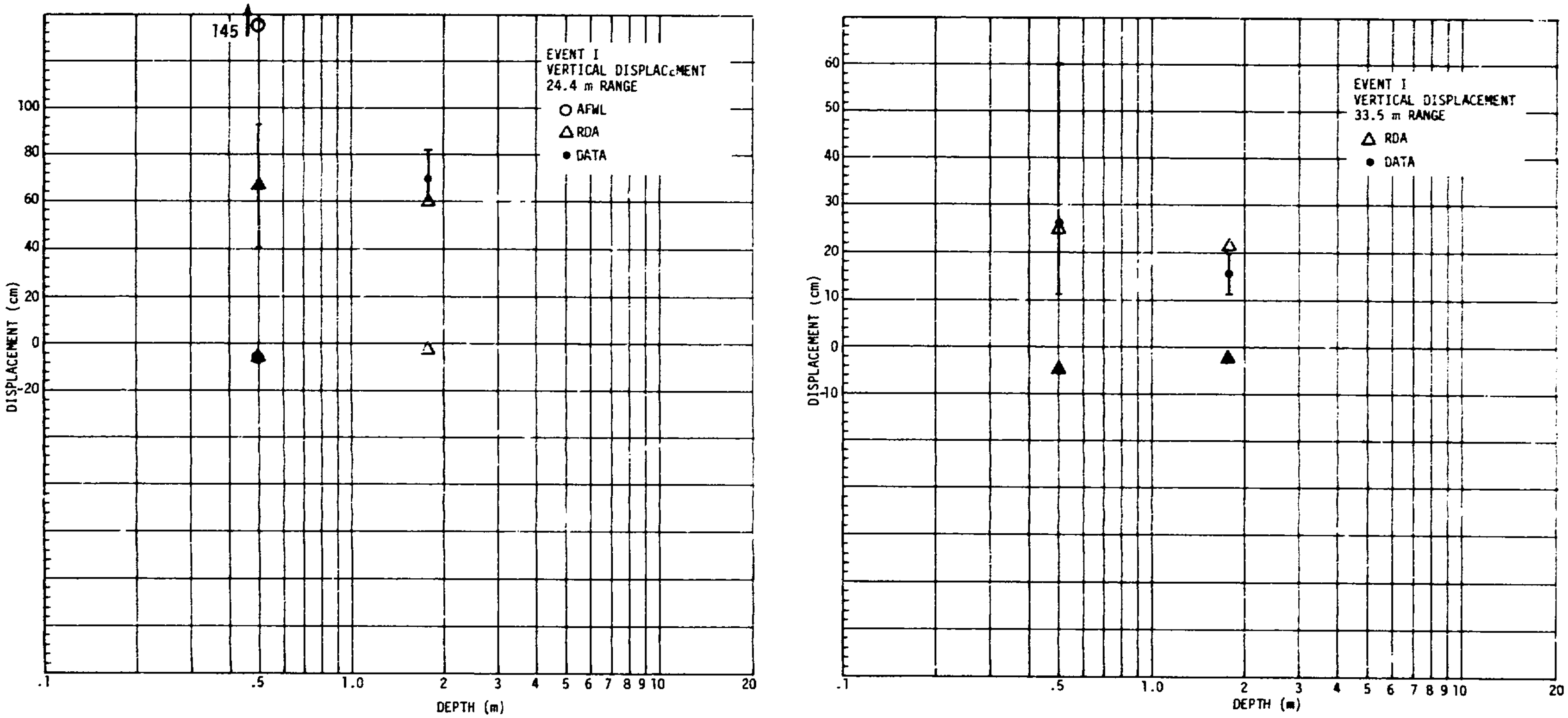


Figure 4.38. Vertical Displacements vs. Depth with Predictions for Pre-DICE THROW II, Event 1

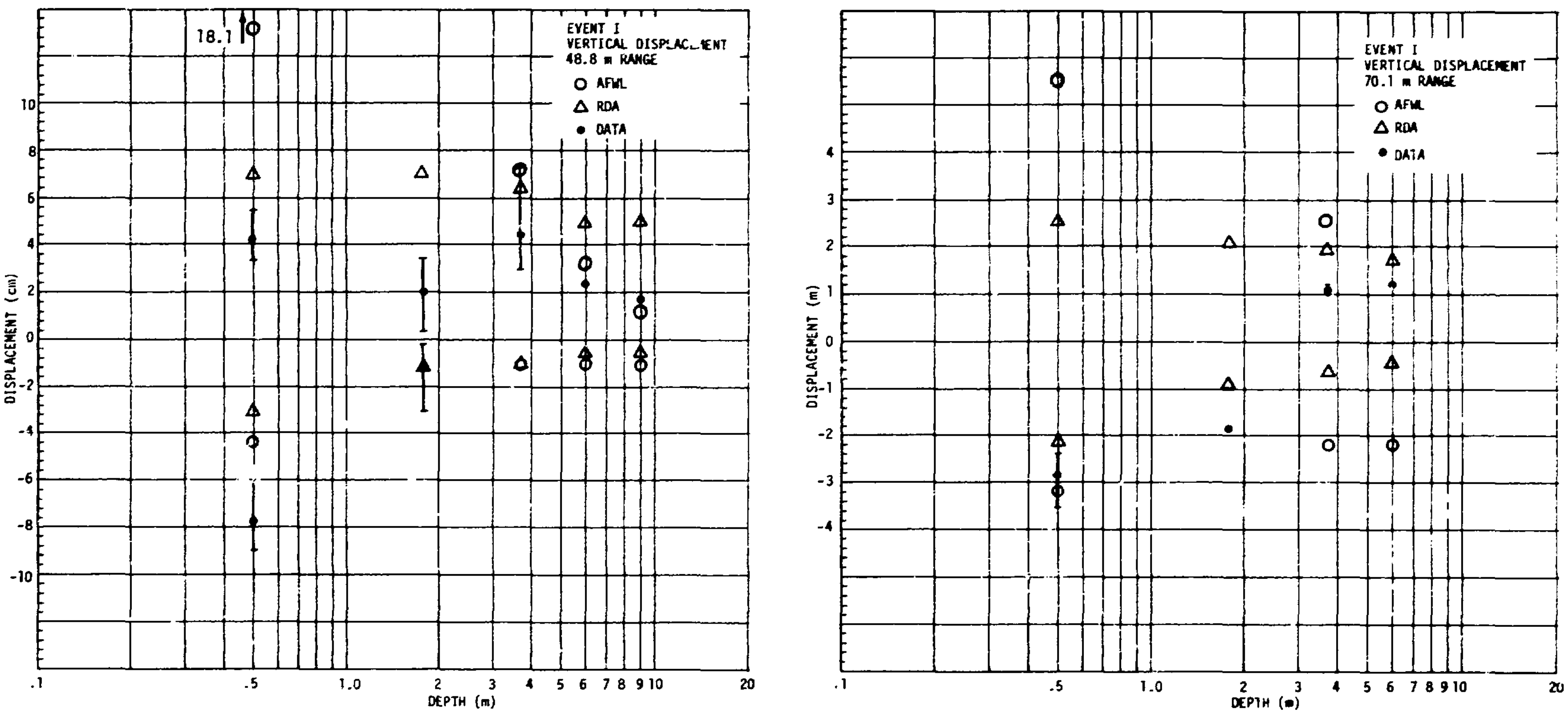


Figure 4.39. Vertical Displacements vs. Depth with Predictions for Pre-DICE THROW II, Event 1

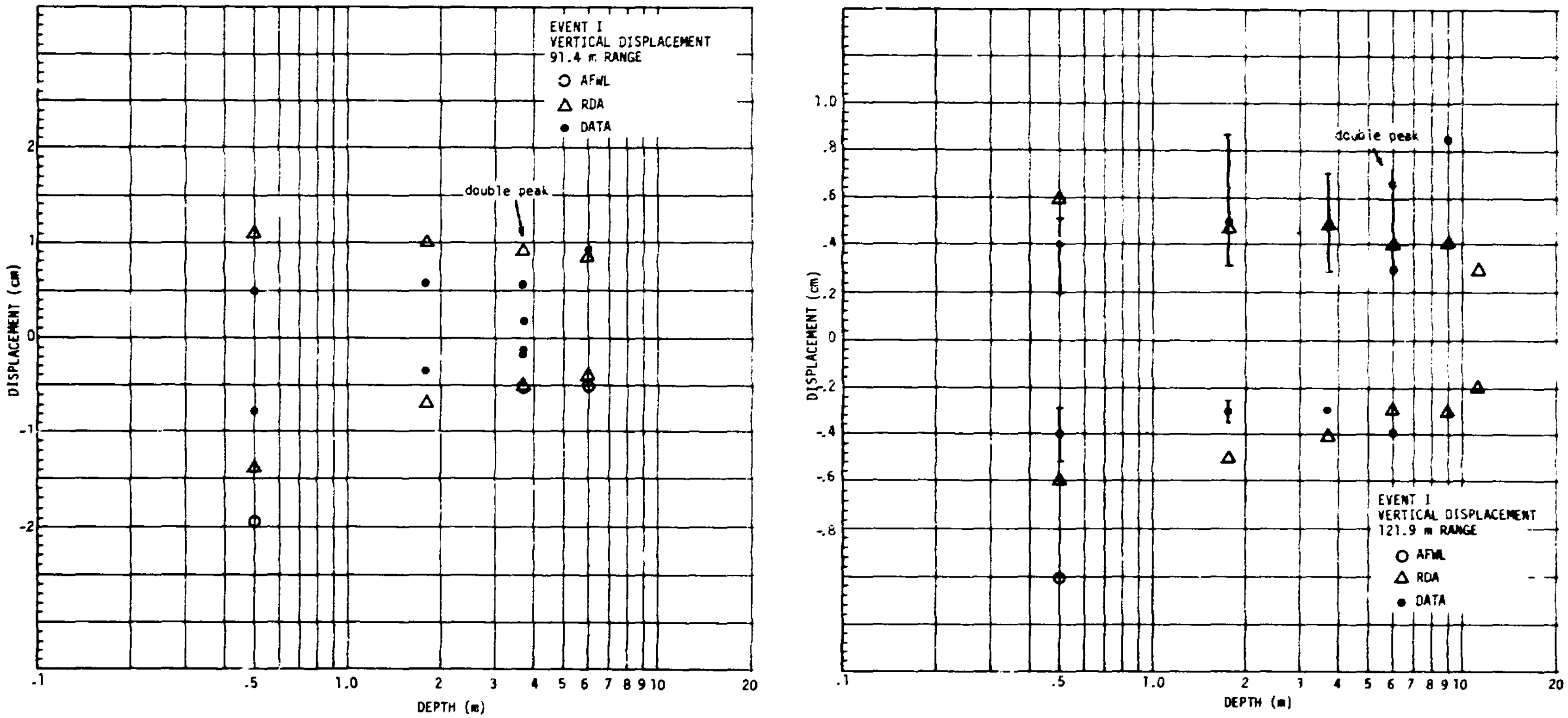


Figure 4.40. Vertical Displacements vs. Depth with Predictions for Pre-DICE THROW II, Event 1

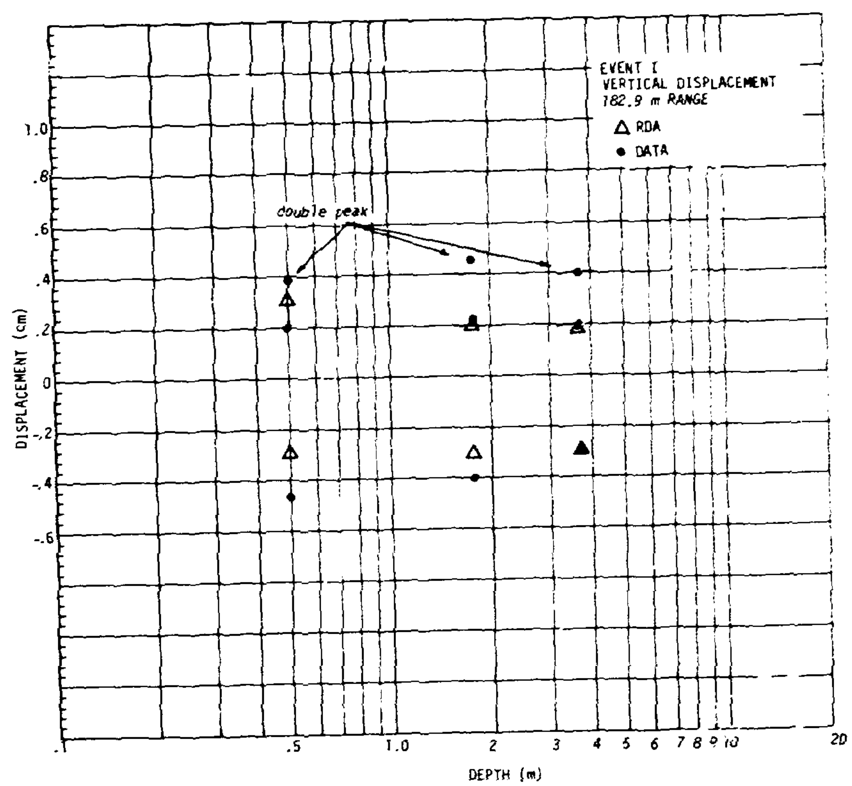


Figure 4.41. Vertical Displacements vs. Depth with Predictions for Pre-DICE THROW II, Event 1

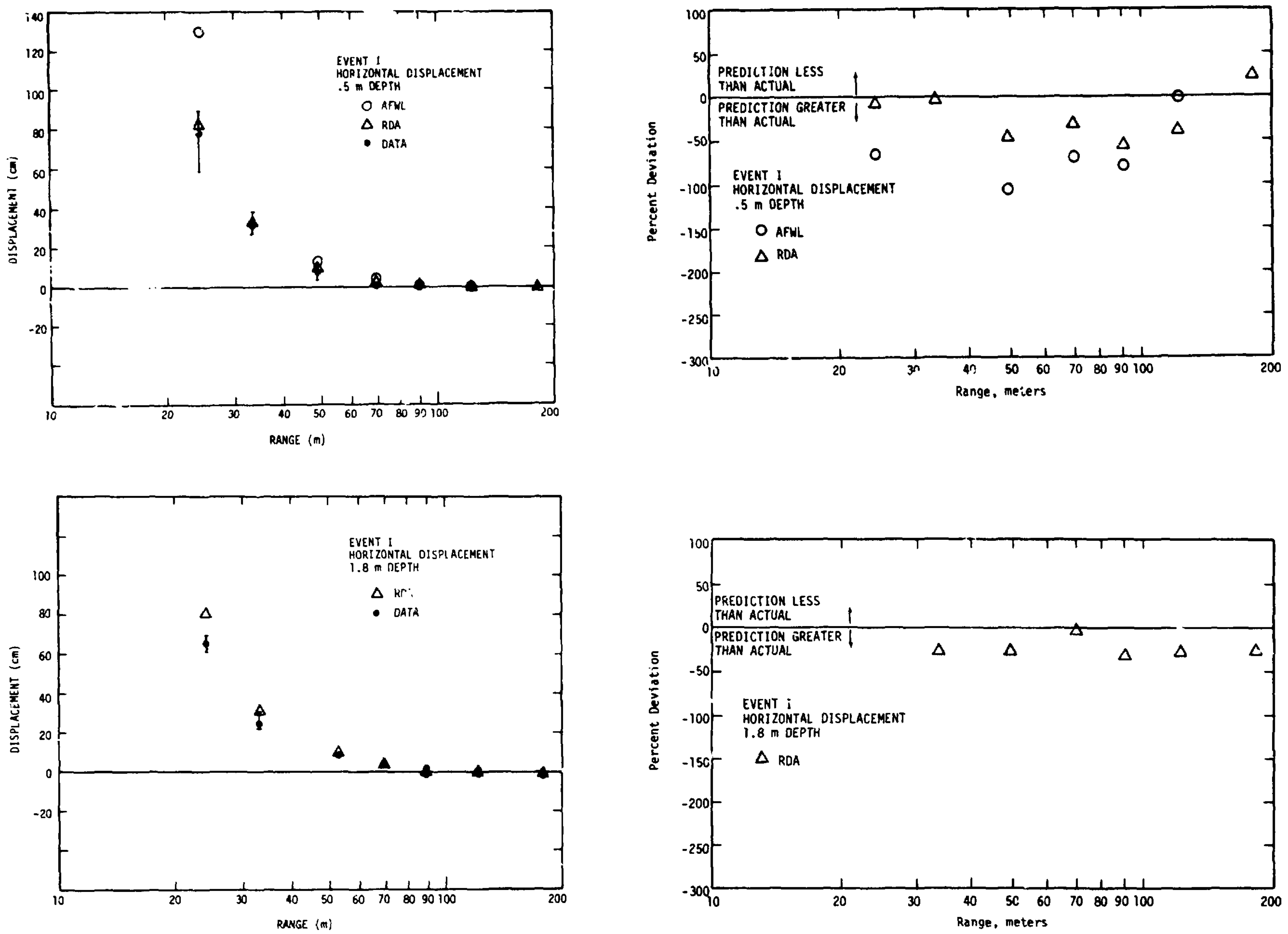


Figure 4.42. Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

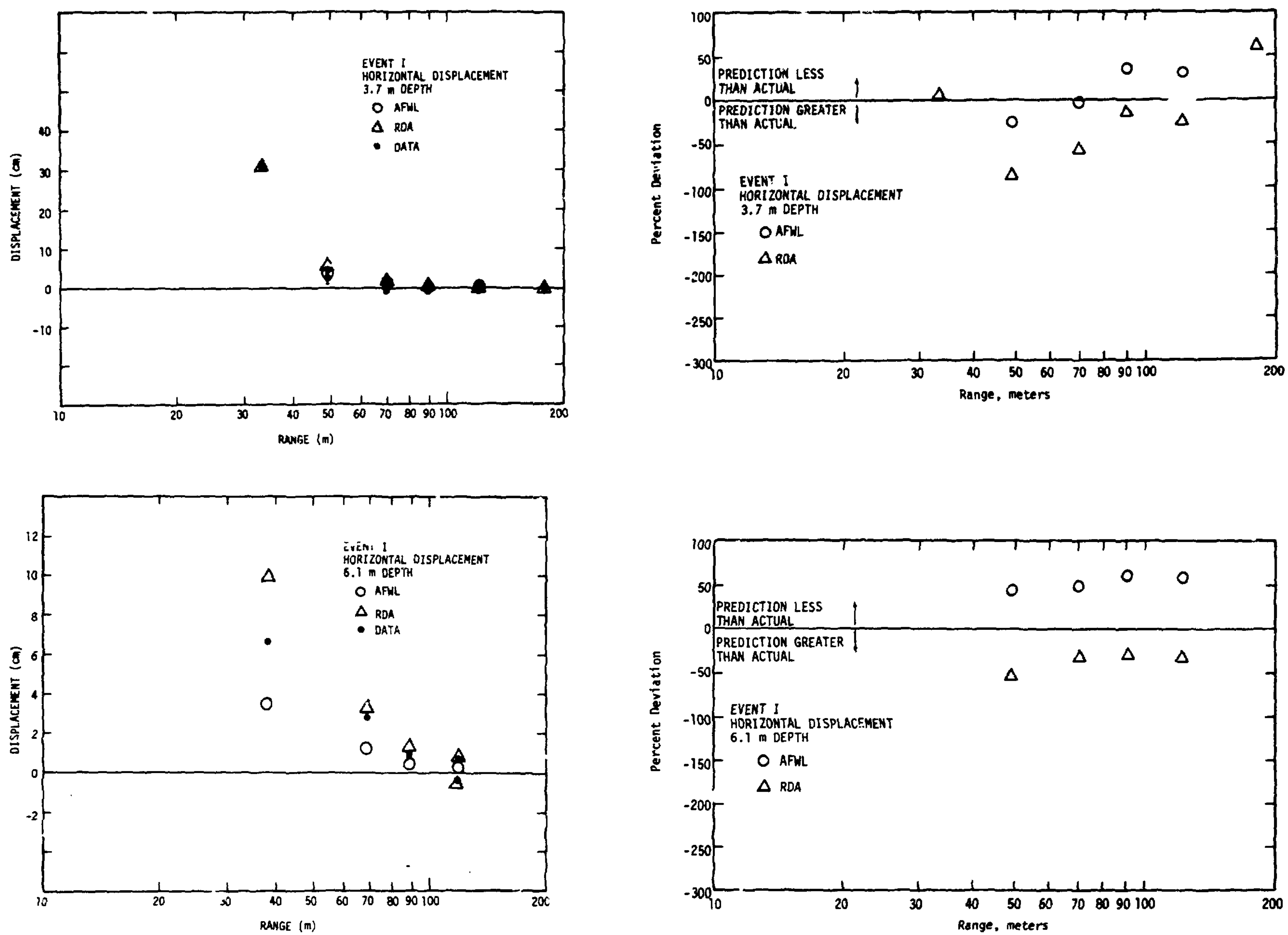


Figure 4.43. Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

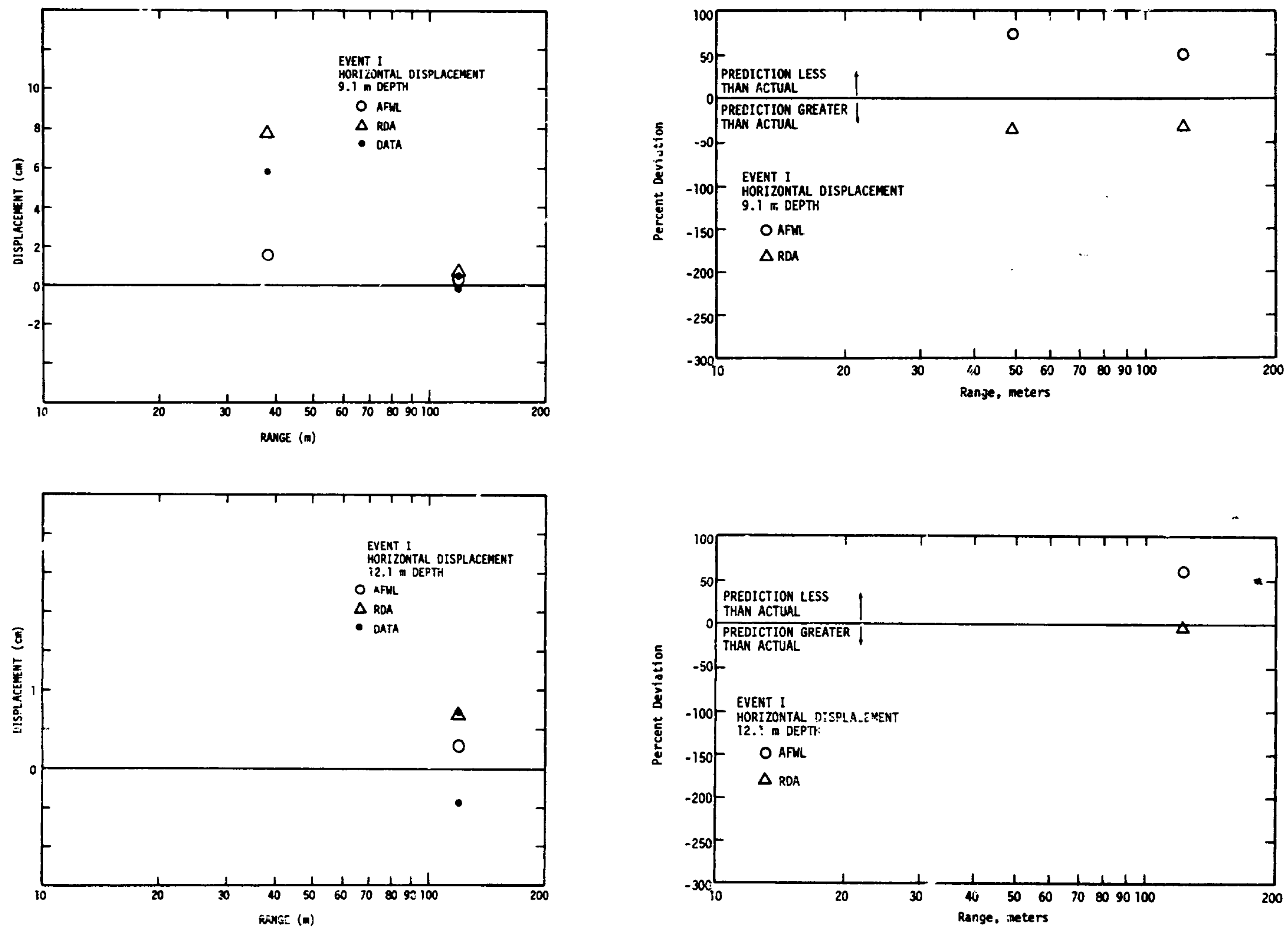


Figure 4.44. Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 1

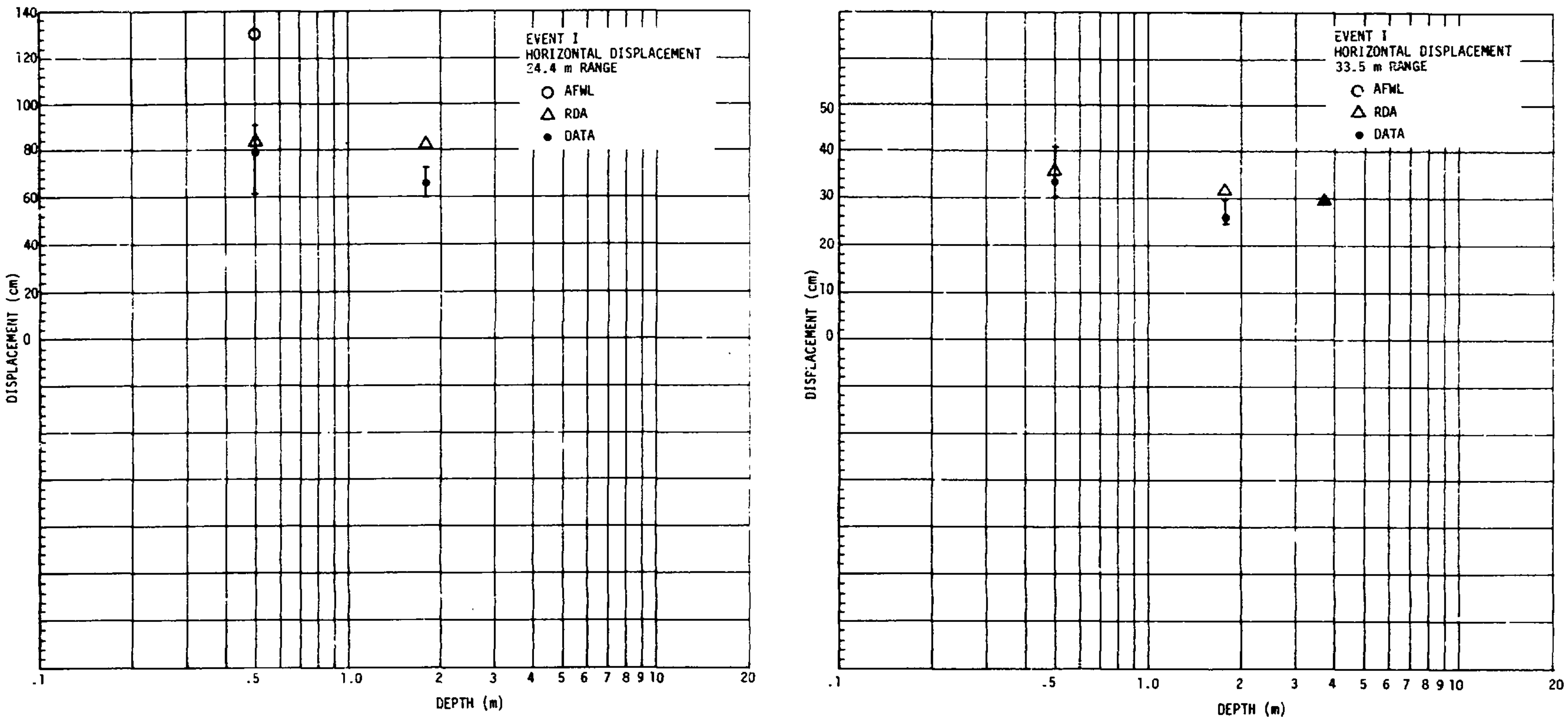


Figure 4.45. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 1

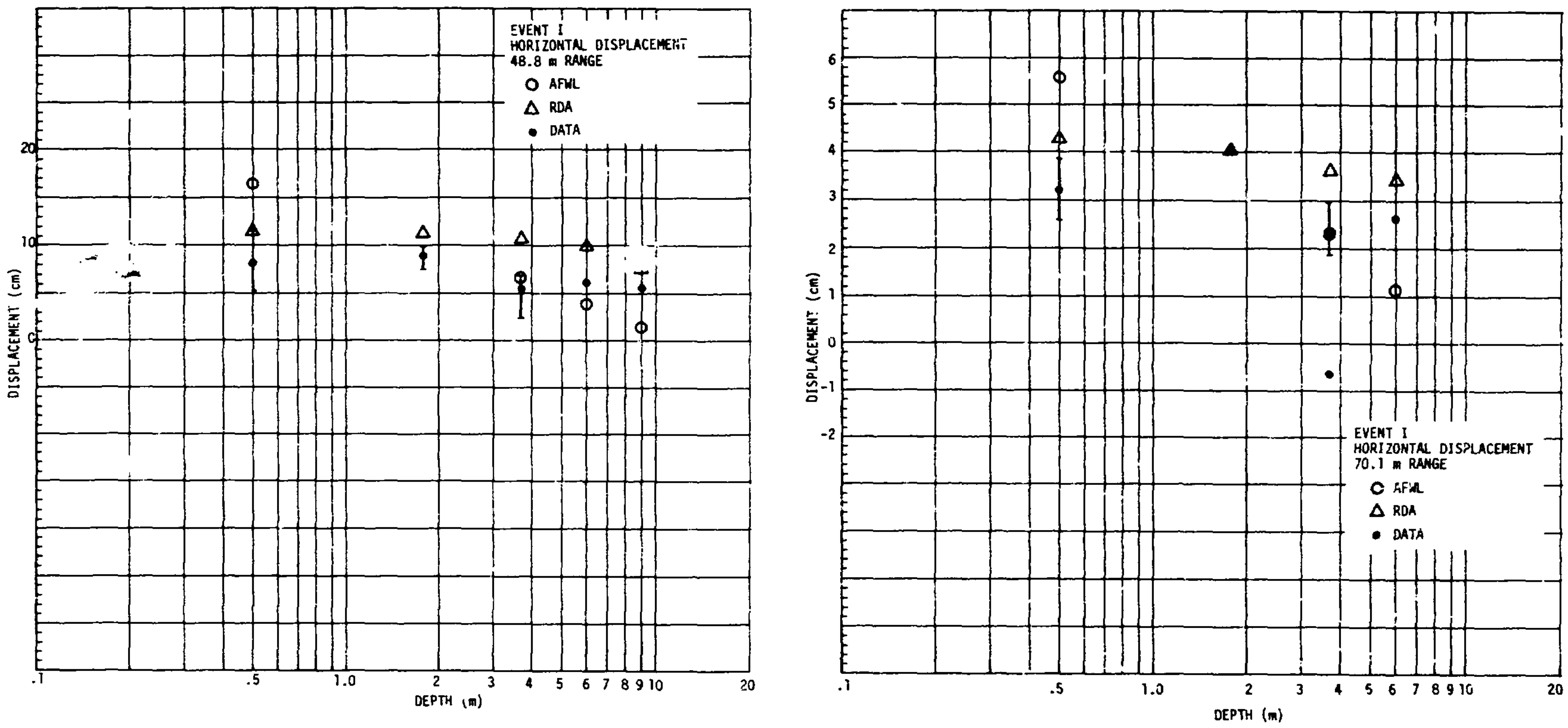
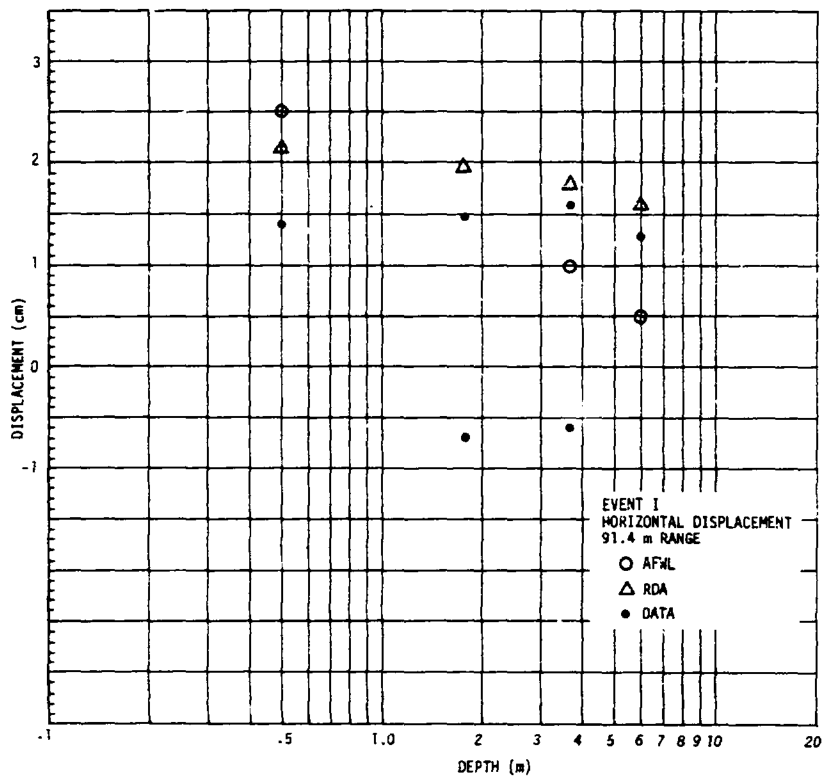


Figure 4.46. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 1



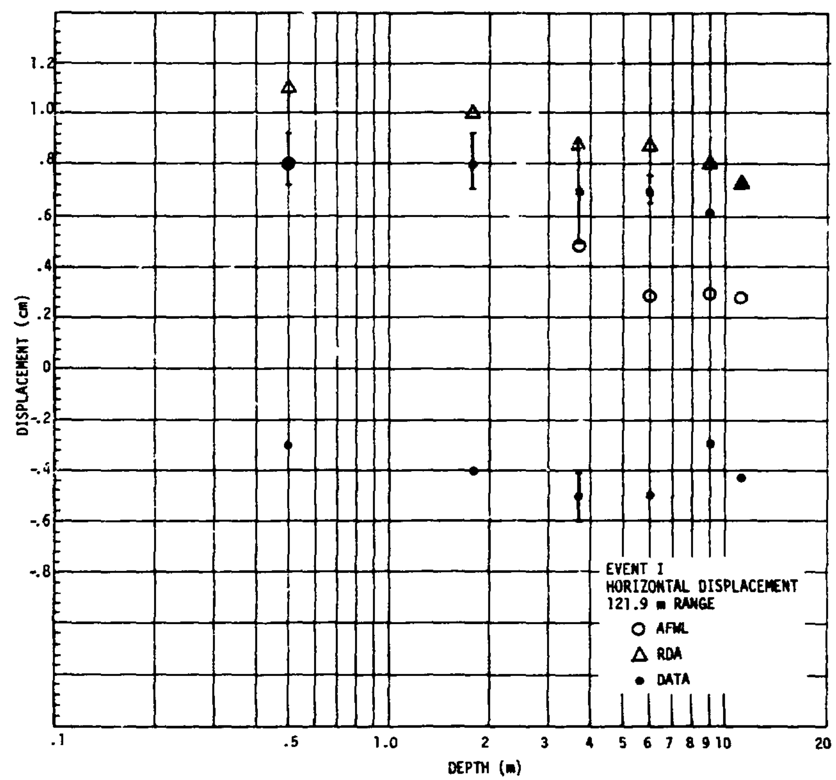


Figure 4.47. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 1

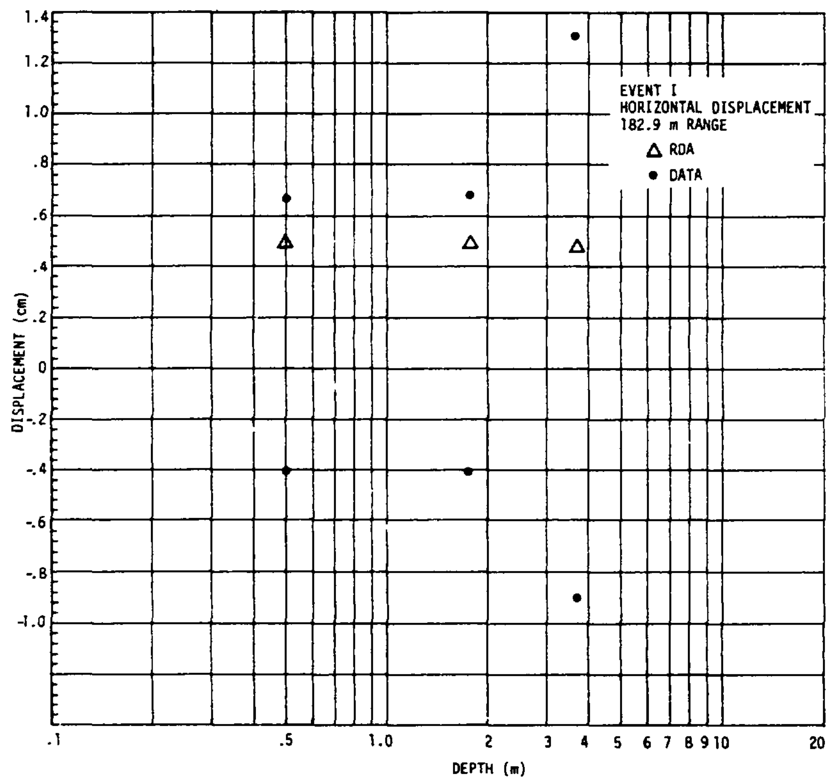


Figure 4.48. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 1

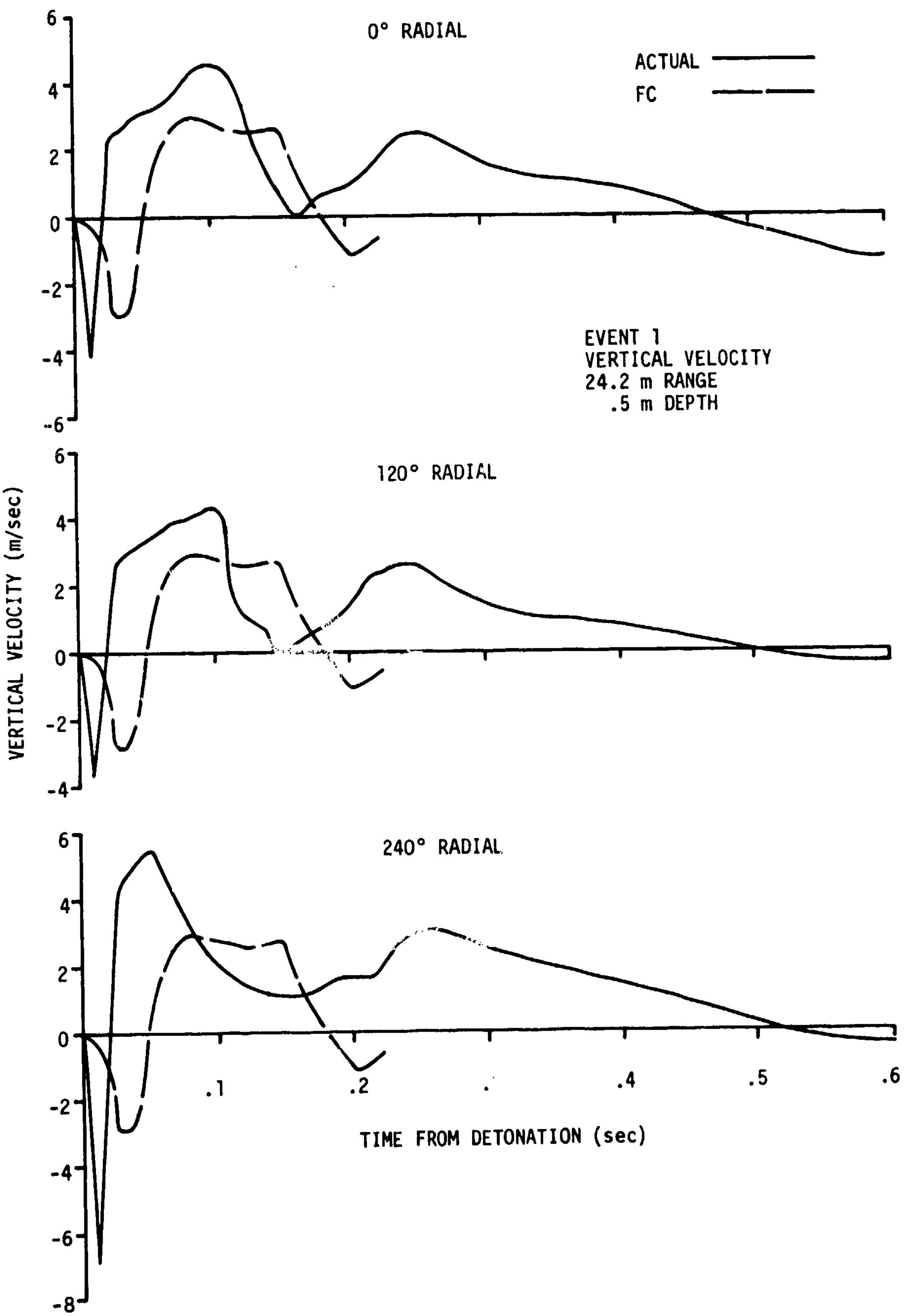


Figure 4.49. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

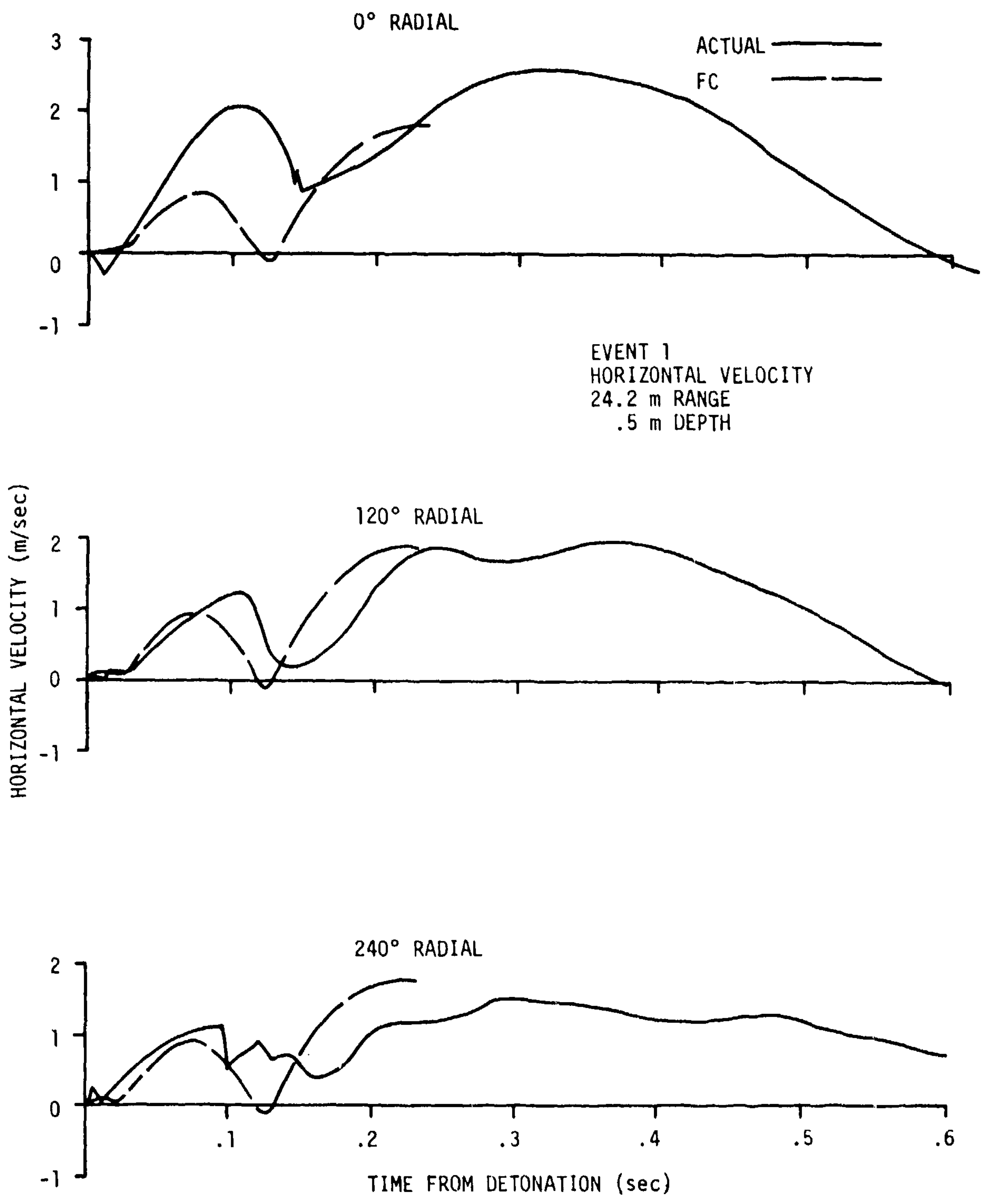


Figure 4.50. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

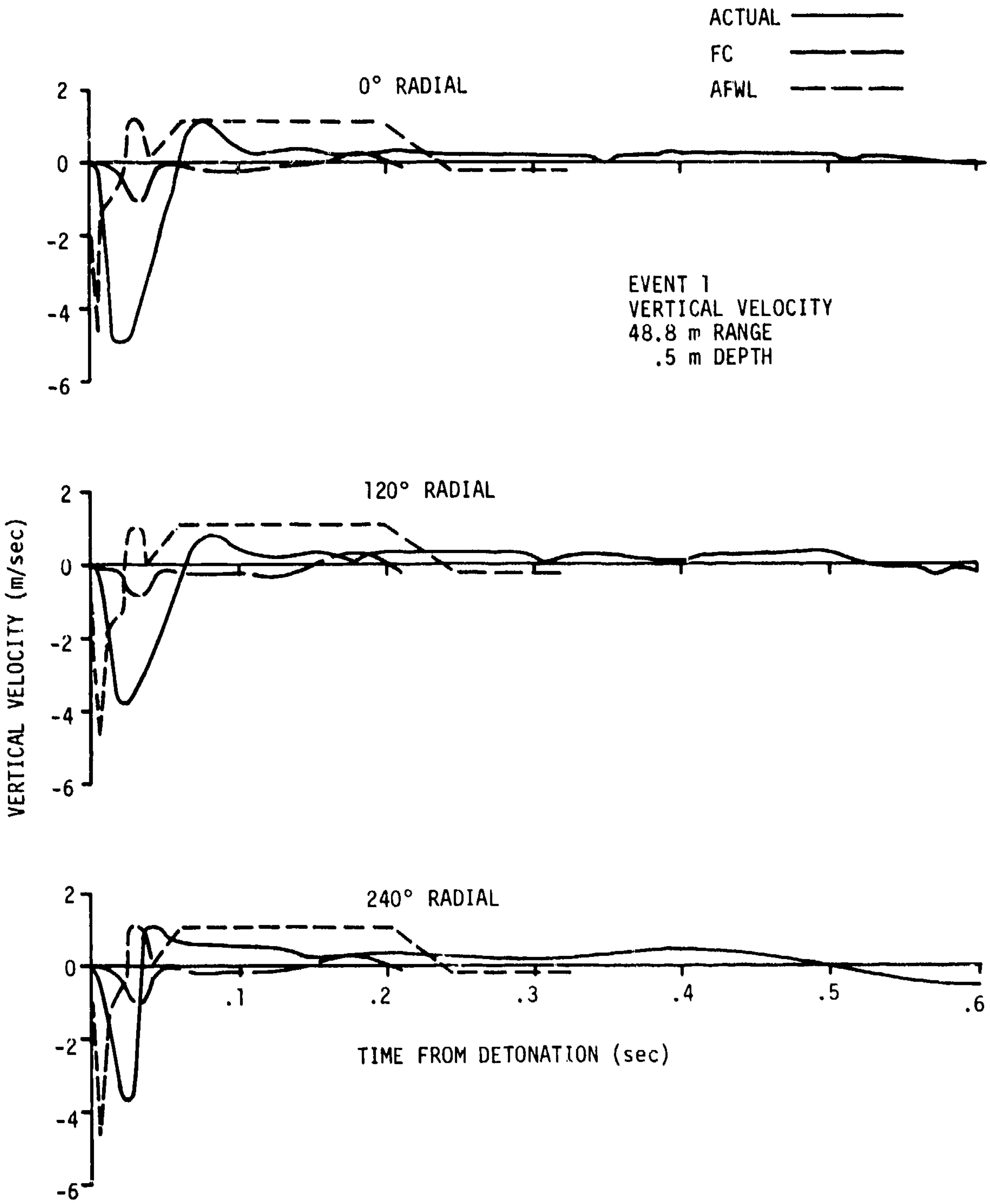


Figure 4.51. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

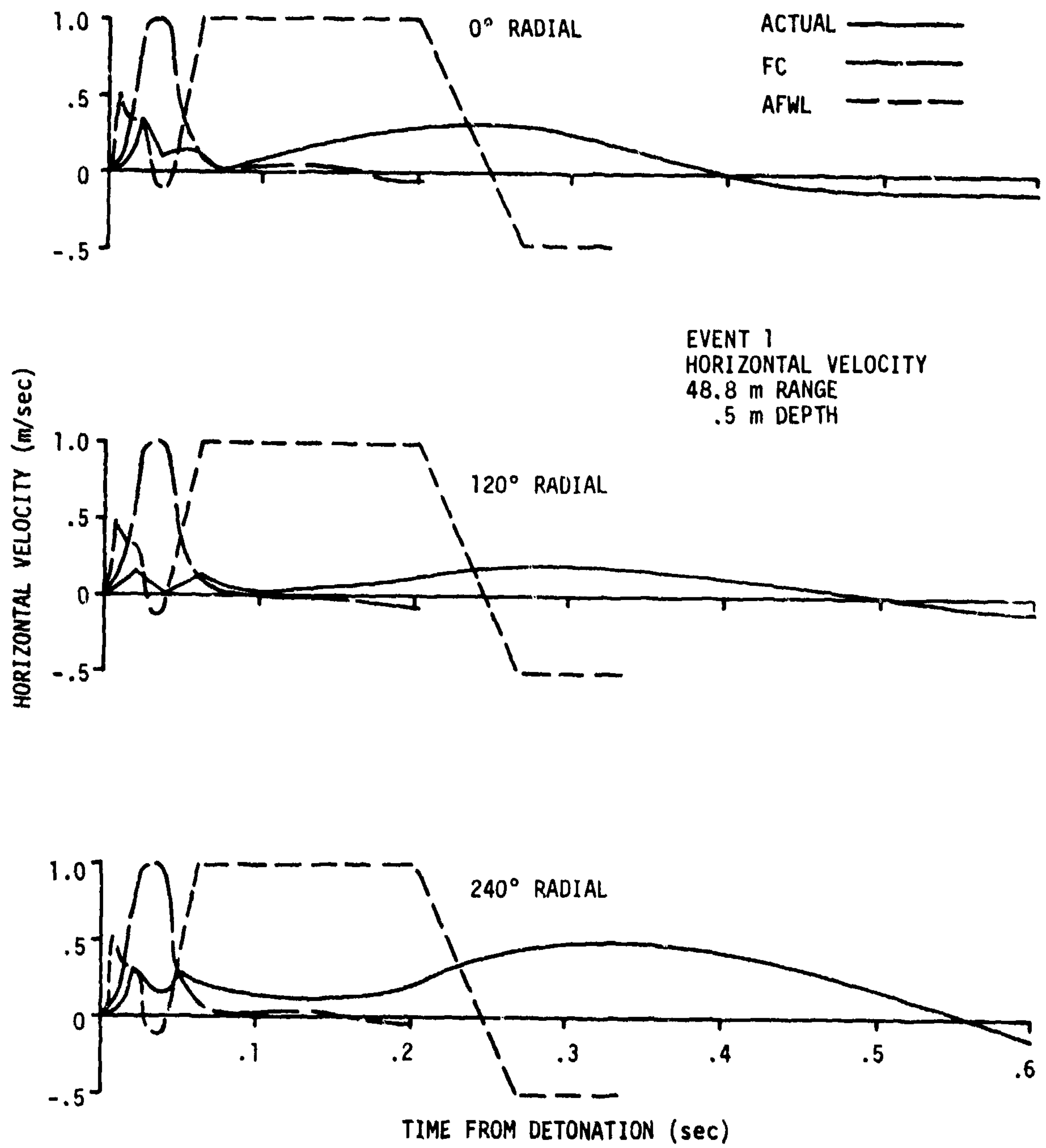


Figure 4.52. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

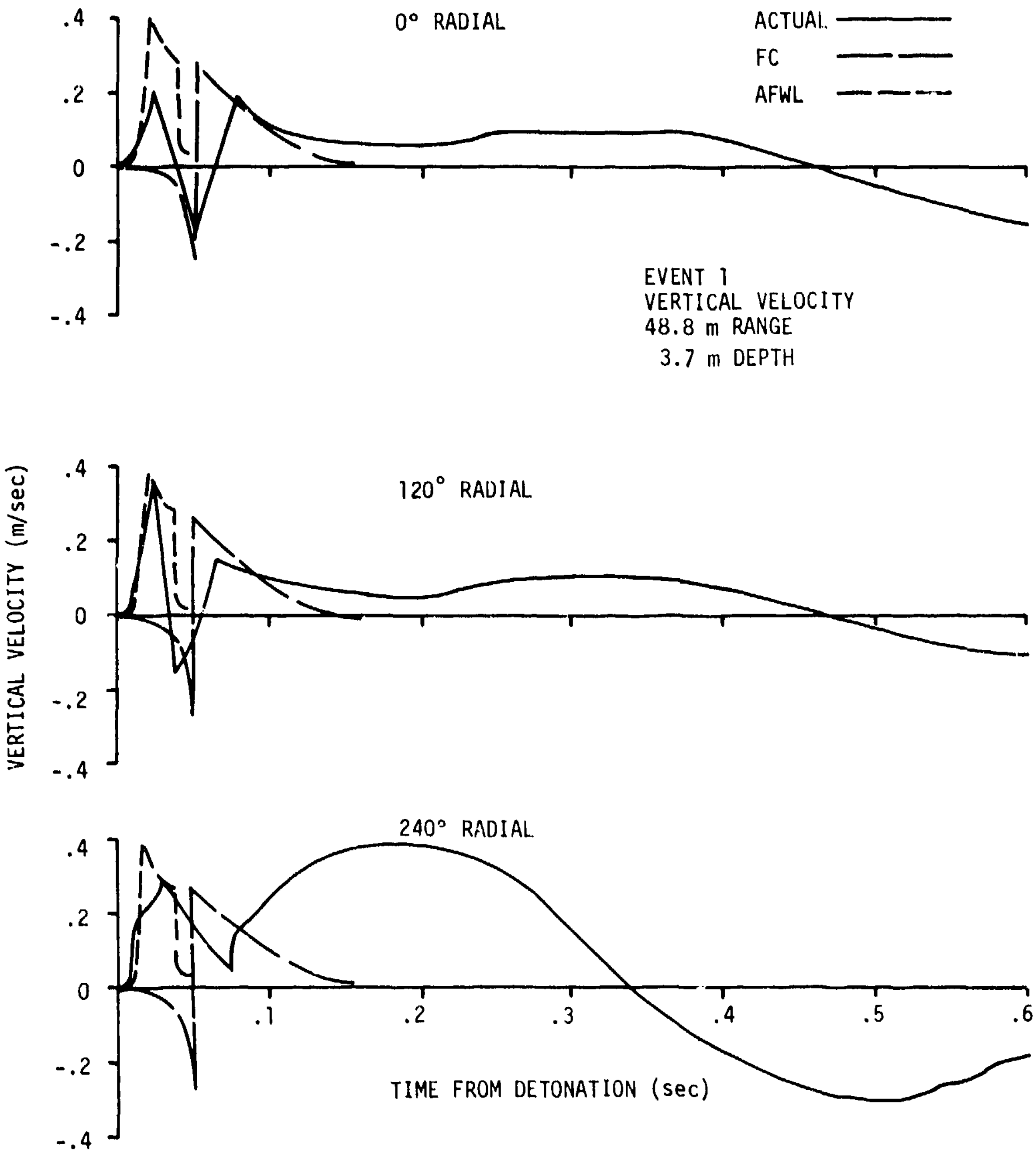


Figure 4.53. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

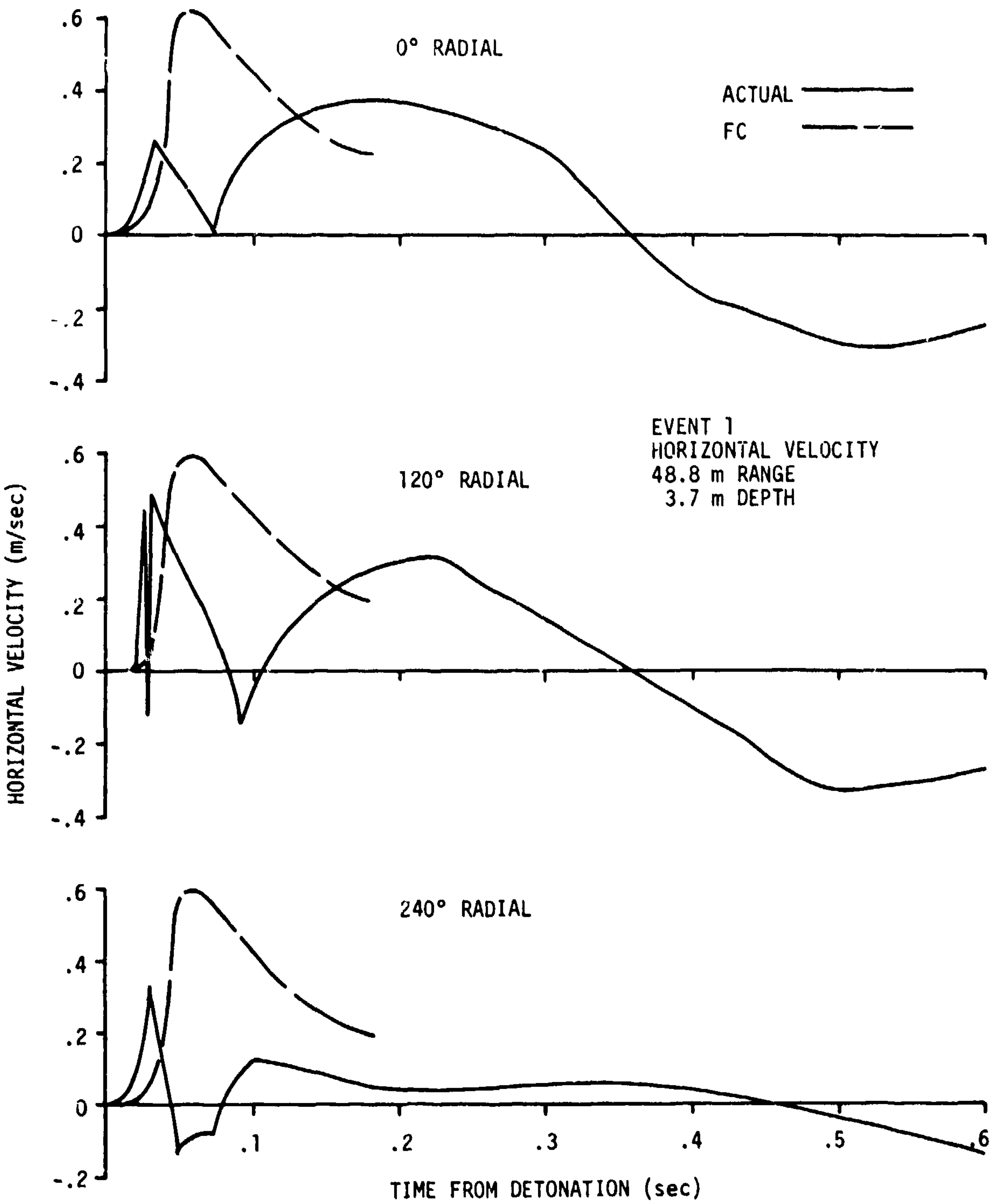


Figure 4.54. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

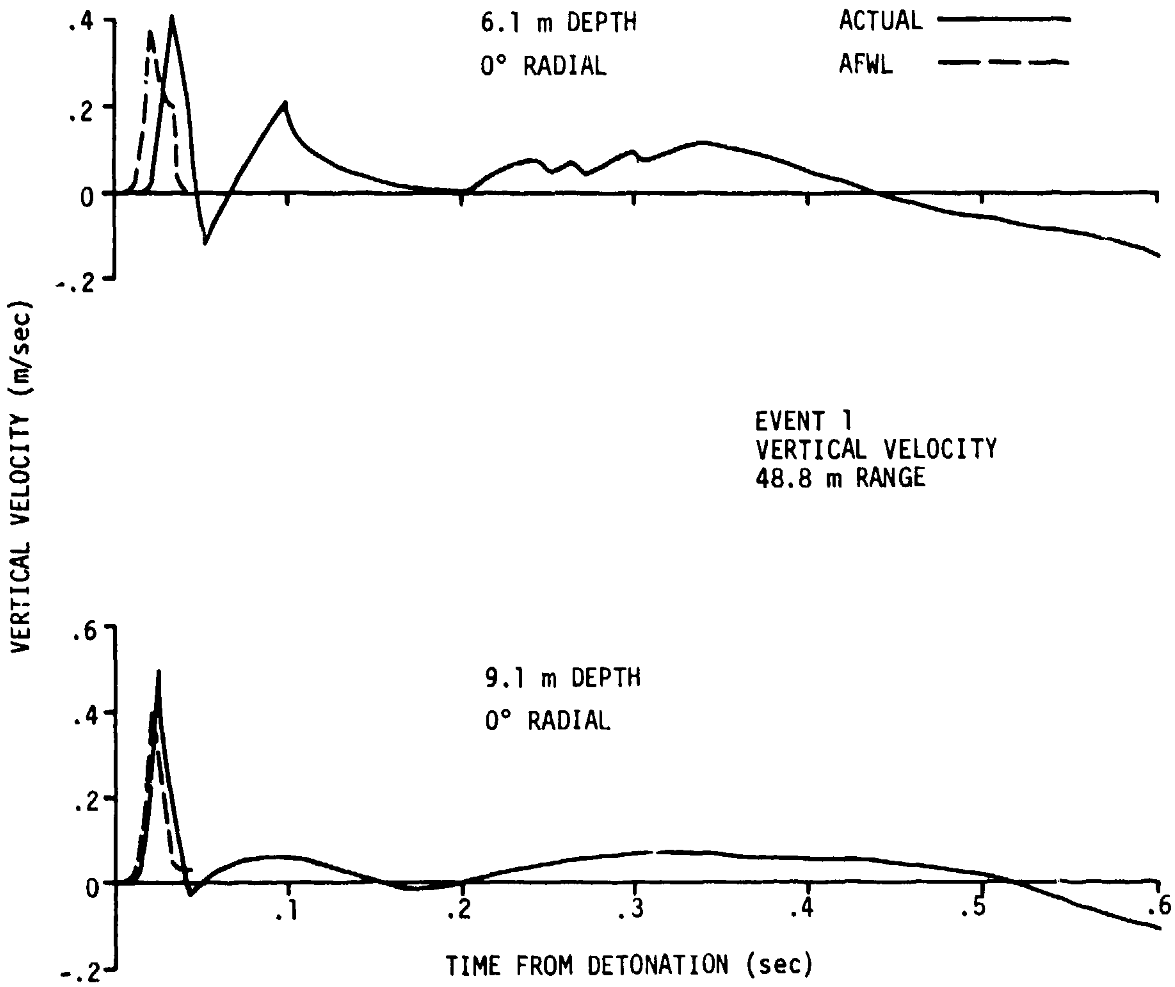


Figure 4.55. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

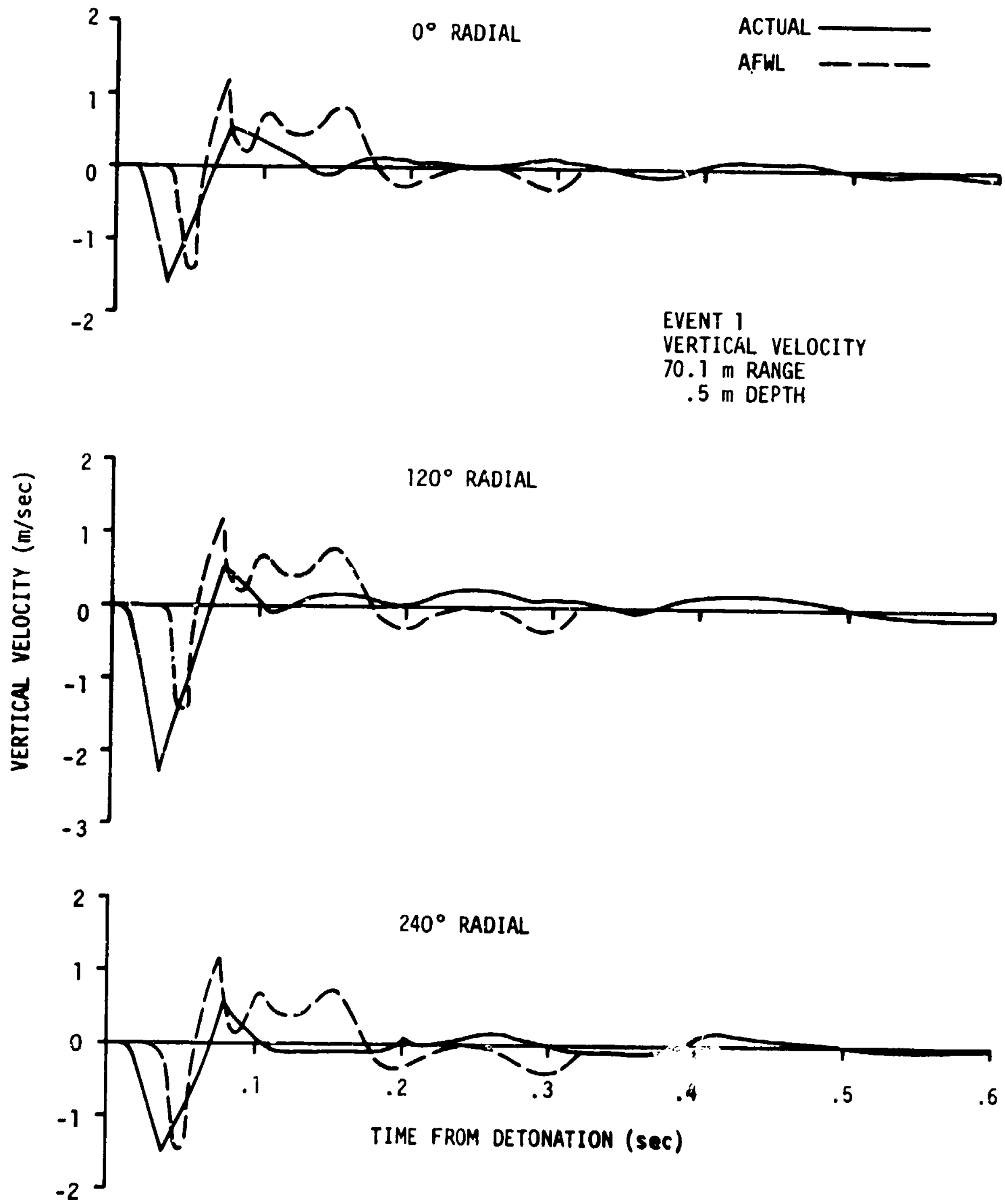


Figure 4.56. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

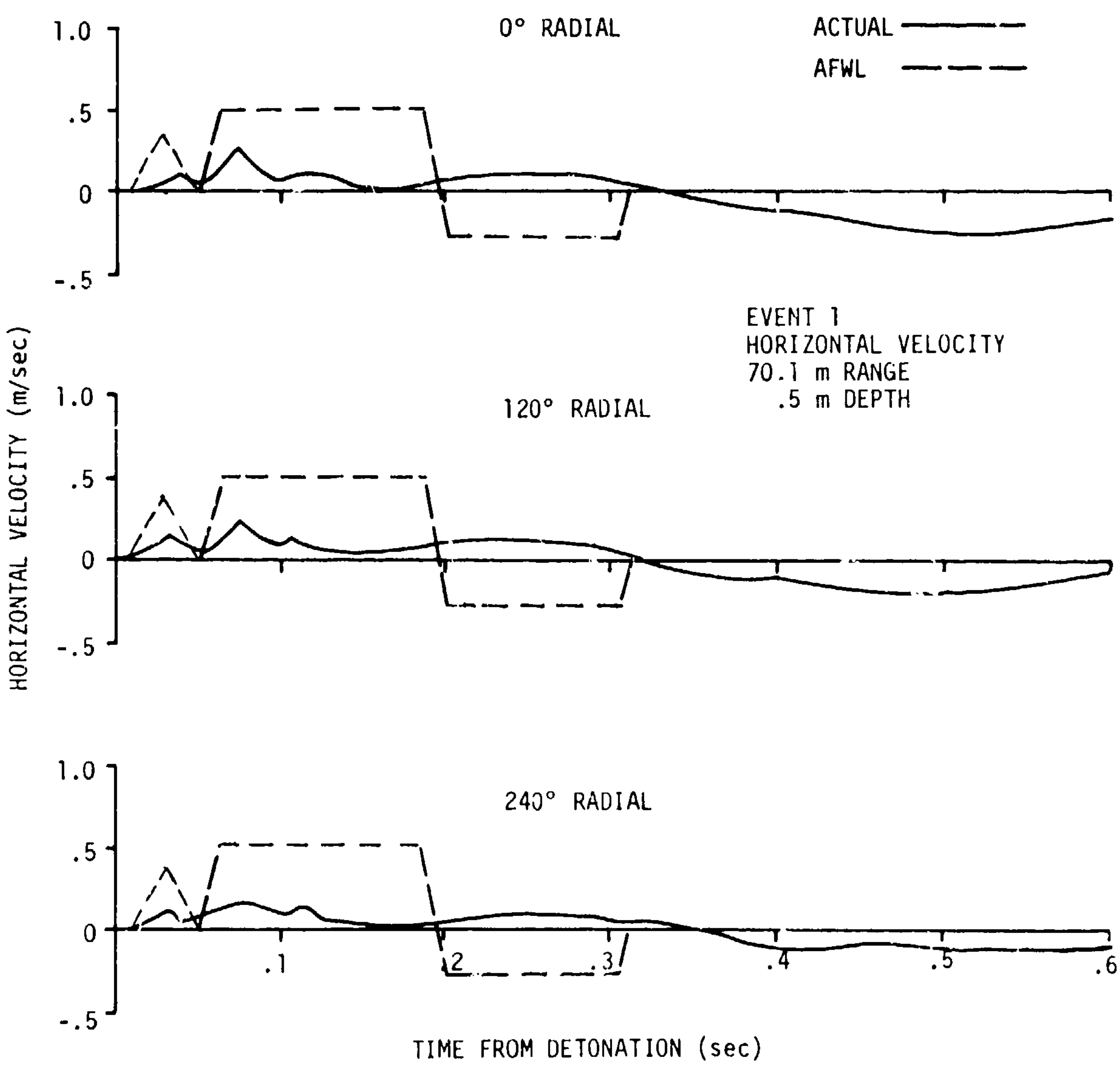


Figure 4.57. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

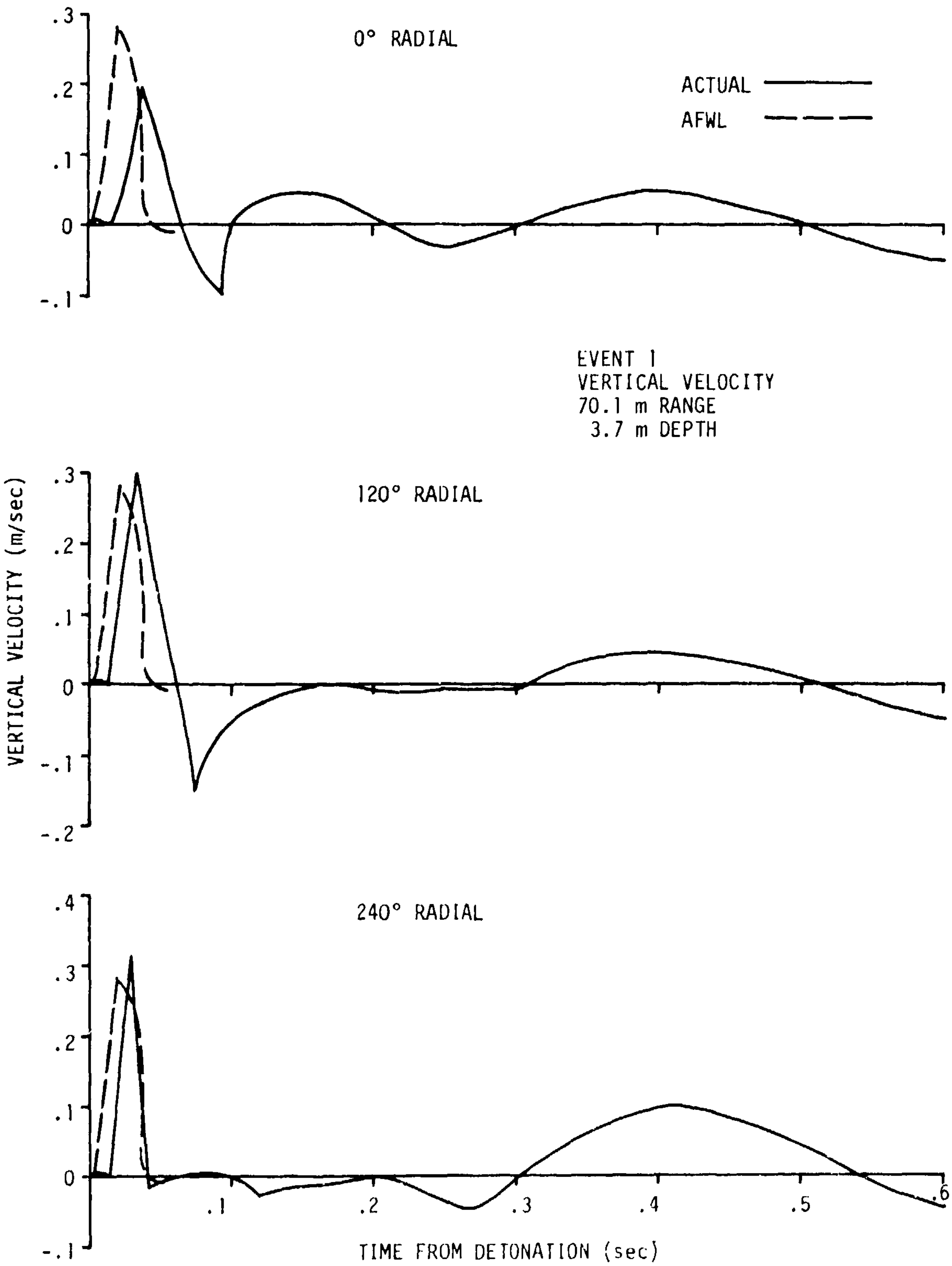


Figure 4.58. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

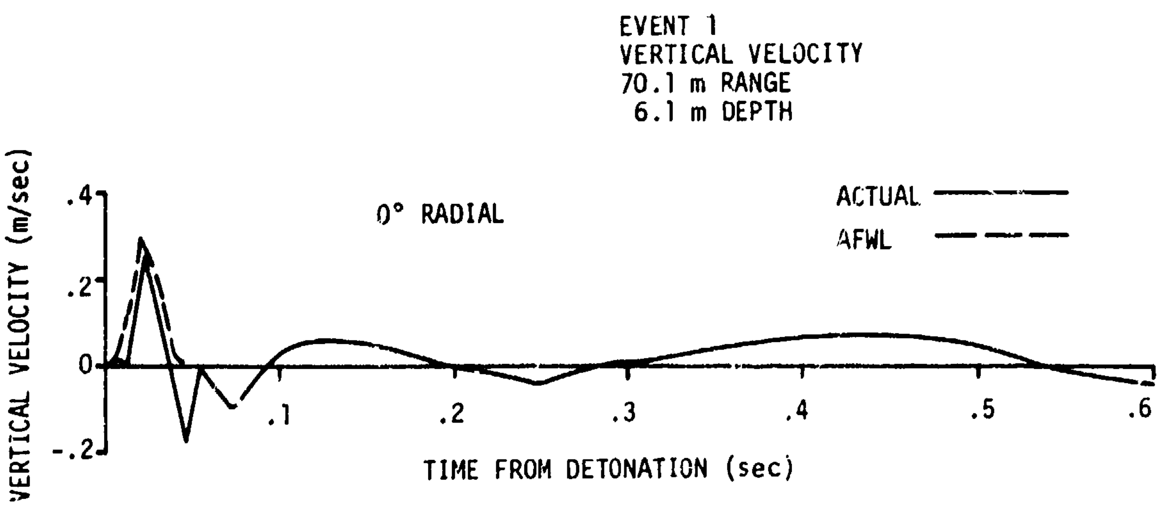


Figure 4.59. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

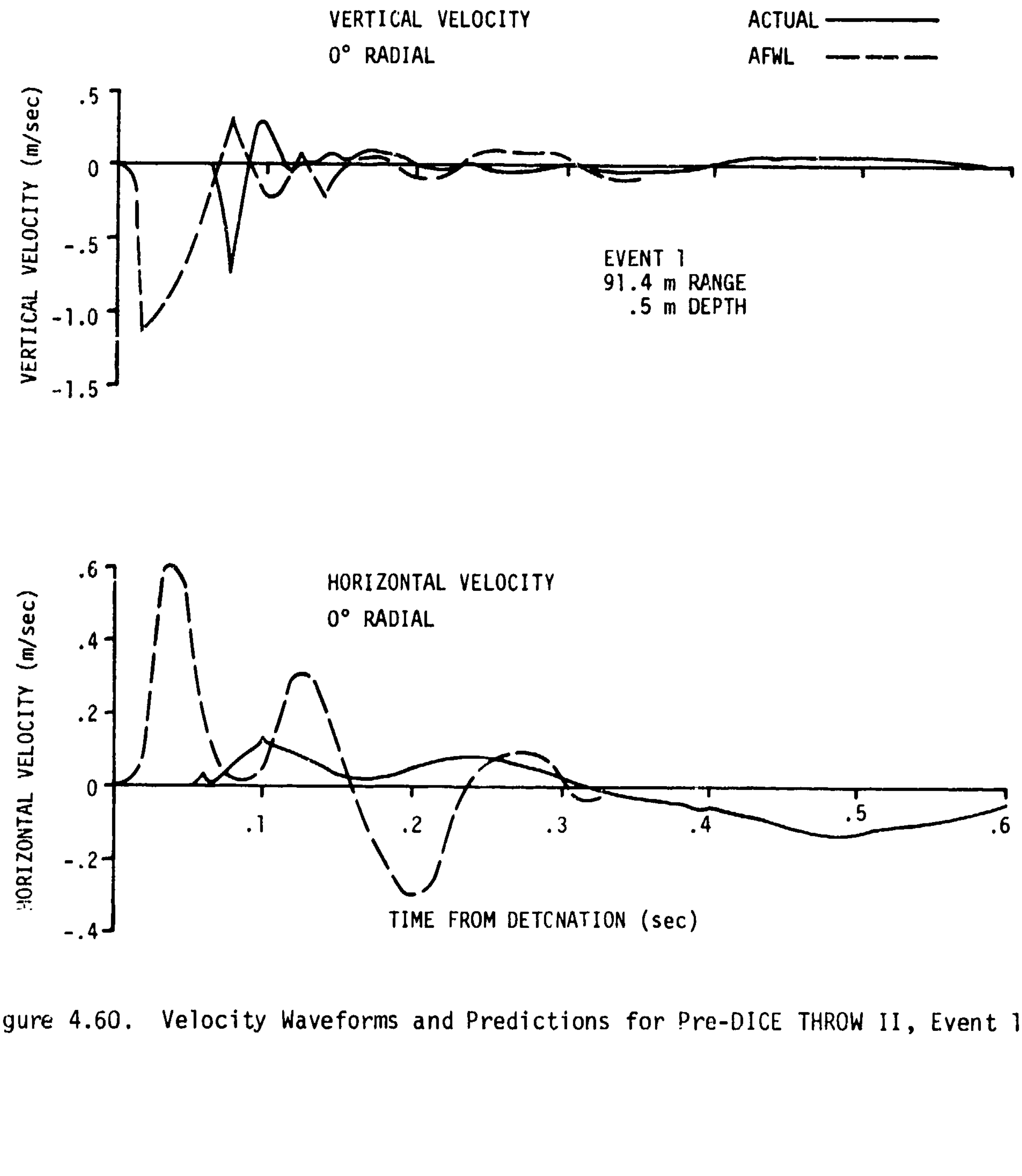


Figure 4.60. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

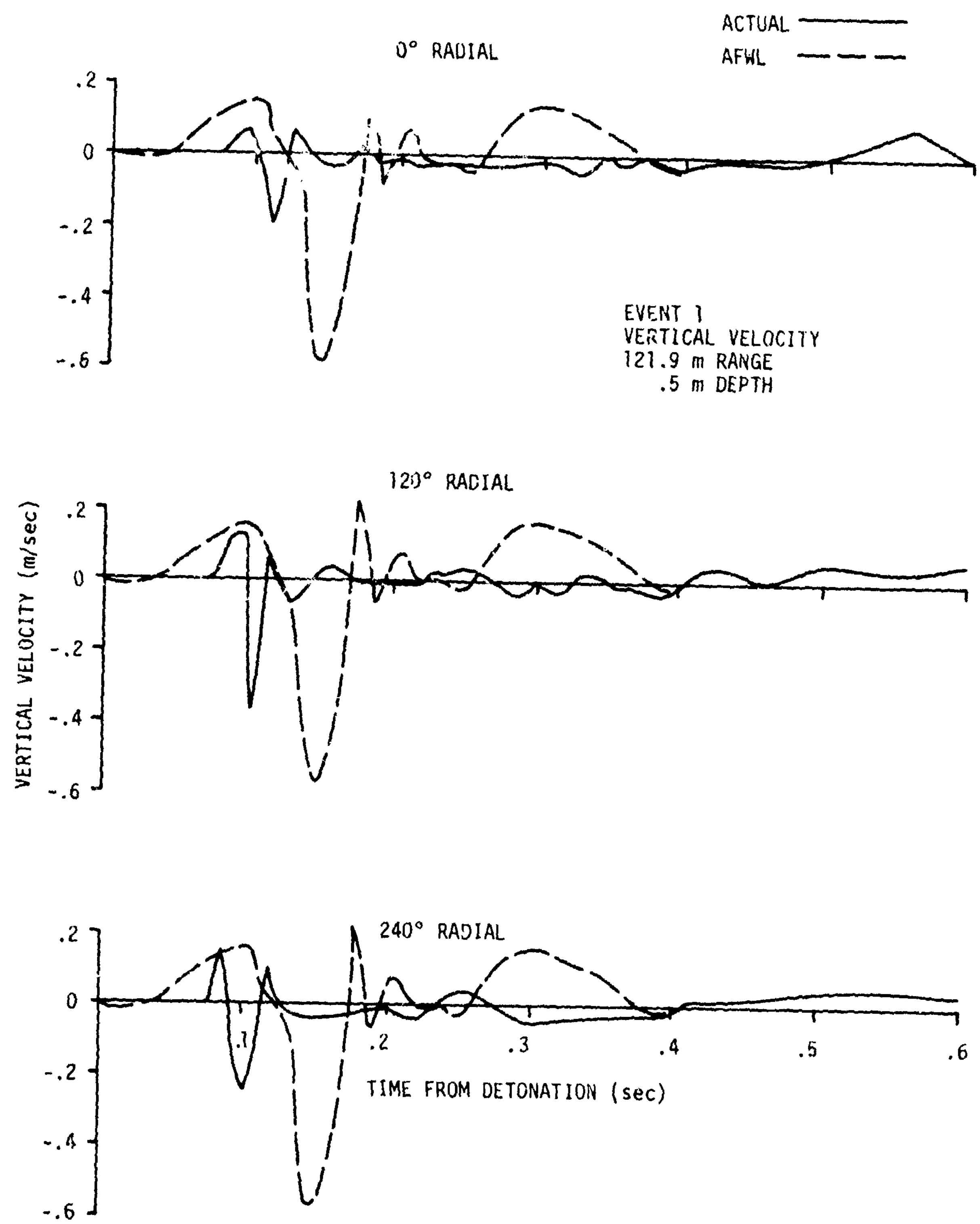


Figure 4.61. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

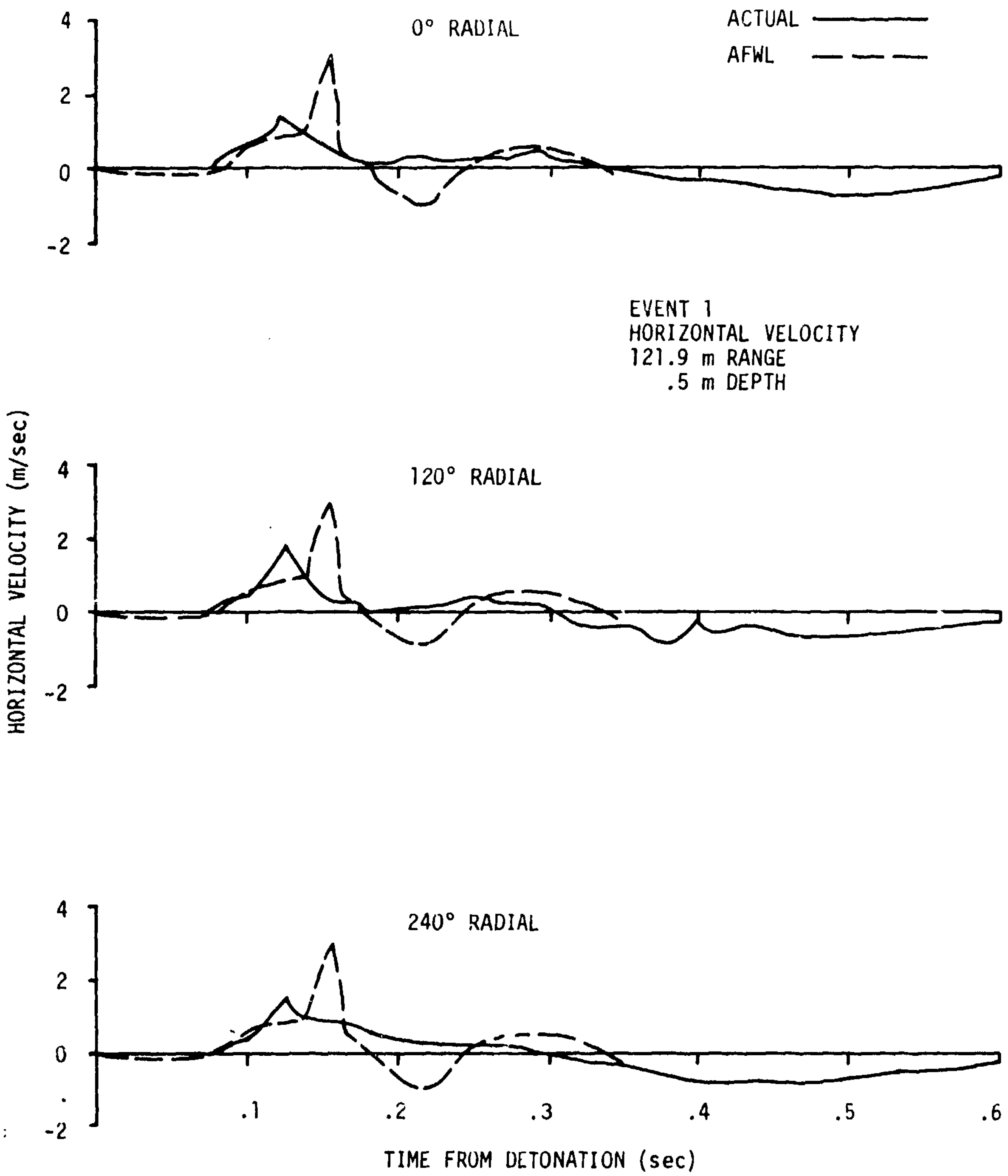


Figure 4.62. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 1

Table 4.4. Observations on Comparisons of AFWL Predictions With Event 1 Data

As compared to data from Event 1, the AFWL predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Airblast Induced or Negative Peaks	Reference Figures
Vertical Acceleration	-	Lower (very few points)	4.1 - 4.9
Vertical Velocity	very close at 0.5 m depth (deviation 50% or less); higher at 3.7 m depth (deviations -125 to -280%	higher at all depths and ranges	4.16 - 4.25
Horizontal Velocity	much higher in nearly every case	-	4.26 - 4.31
Vertical Displacement	higher except for 48.8 m range, 9.1 m depth	lower at 0.5 m depth out to 48.8 m range; higher beyond this range and depth	4.33 - 4.40
Horizontal Displacement	higher at 0.5 m depth; mixed at 3.7 m depth; lower at all other depths	-	4.42 - 4.47

Table 4.5. Observations on Comparisons of RDA Predictions With Event 1 Data

As compared to data from Event 1, the RDA predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Airblast Induced or Negative Peaks	Reference Figures
Vertical Velocity	generally lower at 0.5 m depth; higher at 1.8 m depth; mixed at 3.7 m depth; lower at greater depths	lower to depths of 1.8 m; higher at greater depths	4.16 - 4.25
Horizontal Velocity	higher except at far-out ranges and greatest depths	-	4.26 - 4.32
Vertical Displacement	lower at close-in and far-out ranges; generally higher at middle ranges	lower out to 70.1 m range and 1.8 m depth; higher at greater ranges to same depths; mixed at depths of 3.7 m and greater	4.33 - 4.41
Horizontal Displacement	generally higher in all cases	-	4.42 - 4.48

Table 4.6. Observations on Comparisons of FC Predictions with Event 1 Data

As compared to data from Event 1, the FC/DNA predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Reference Figures
Vertical Velocity	Lower at close-in station (24.4 m range and 0.5 m depth); higher at 48.8 m range and 0.5 m depth; good agreement at 3.7 m depth	4.16 - 4.23
Horizontal Velocity	lower at close-in station (24.4 m range and 0.5 m depth); higher at greater ranges and depths.	4.26 - 4.30

Table 4.7. Observations on Comparisons of WES Predictions With Event 1 Data

As compared to data from Event 1, the WES predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Reference Figures
Vertical Acceleration	higher at 0.5 m and 1.8 m depths; lower at 3.7 m depth out to 33.5 m range, higher beyond that range; lower at depths greater than 3.7 m.	4.1 - 4.9
Horizontal Acceleration	higher at close-in ranges (12.2 and 18.3 m) at 1.8 m depth; mixed at greater ranges at this depth; higher at depths 3.7 m and greater.	4.10 - 4.15
Vertical Velocity	higher except at 9.1 m depth	4.16 - 4.25
Horizontal Velocity	higher at all ranges at 0.5 m depth; higher out to 121.9 m range at other depths; lower at greater ranges.	4.26 - 4.32

Table 4.8. Data versus Prediction Summary for Pre-DICE THROW II, Event 1

		AFWL	RDA	FC	WES
VERTICAL ACCELERATION:	DI	none	none	none	mixed
	AI	less*	none	none	none
HORIZONTAL ACCELERATION:	DI	none	none	none	gen. greater
VERTICAL ACCELERATION:	DI	gen. greater	mixed	mixed	gen. greater
	AI	greater	mixed	none	none
HORIZONTAL VELOCITY:	DI	greater	gen. greater	mixed	gen. greater
VERTICAL DISPLACEMENT:	DI	gen. greater	mixed	none	none
	AI	none	mixed	none	none
HORIZONTAL DISPLACEMENT:	DI	mixed	gen. greater	none	none

*less - means the predictions are less than the data

CHAPTER 5

COMPARISON OF DATA AND PREDICTIONS; EVENT 2

This chapter is identical to Chapter 4 except that data from the 120-ton ANFO detonation, Event 2, was used as a base against which comparisons were made. The predictions in all cases were the same for both events, so any differences between the comparisons presented here and those of Chapter 4 will be entirely due to differences in the experimental data base.

A. TABULATED AND GRAPHICAL PRESENTATIONS

The material here is organized exactly the same as that in Chapter 4, and many of the comments made in that chapter also apply here. Therefore, the reader is advised to look at Chapter 4 before proceeding.

Experimental and predicted peak values for acceleration, velocity, and displacement, respectively, are given in Tables 5.1, 5.2, and 5.3. Percentage deviations, calculated as previously described, are also given in the tables. As there were fewer ground motion data recorded on Event 2 than on Event 1, the tables are somewhat shorter than those in Chapter 4.

Graphical presentations of the tabulated data comprise Figures 5.1 through 5.39. As before, in the case of vertical motions, an effort is made to separate the direct induced (positive) and airblast induced (negative) motions. The horizontally oriented gages record both types of motion in the positive (outward) direction, and in these cases no attempt is made to separate the two motions. Peak positive and negative excursions of the traces are recorded.

Vertical acceleration data and predictions are plotted versus range in Figures 5.1 through 5.4. Deviations of the predictions are also given. The same data are given as functions of depth in Figures 5.5 and 5.6. The corresponding horizontal acceleration data is plotted against range in Figures 5.7 through 5.9 and against depth in Figures 5.10 and 5.11.

Figures 5.12 through 5.16 present the vertical velocity data and deviations for Event 2 versus range. Figures 5.17 through 5.19 show this same data as functions of depth. The horizontal velocity data is given versus range in Figures 5.20 through 5.22 and versus depth in Figures 5.23 through 5.25.

Displacement predictions and integrations of the velocity traces are also presented graphically, as are the calculated deviations for this data. Vertical displacements are plotted versus range in Figures 5.26 through 5.30, and versus depth in Figures 5.31 through 5.33. Horizontal displacements versus range are presented in Figures 5.34 through 5.36. The same horizontal displacements appear as functions of depth in Figures 5.37 through 5.39.

A few comparisons of predicted and experimentally obtained waveforms are also possible for the data of Event 2. These comparisons are restricted to vertical and horizontal velocity traces. As before, certain features of the records are remarkably well predicted, while others leave much to be desired. The traces are reproduced in Figures 5.40 through 5.52.

B. OBSERVATIONS ON EVENT 2 COMPARISONS

Tables 5.4 through 5.7 are used to present observations on the graphical representations of the data comparing predictions with Event 2 data. The format is exactly as that of Chapter 4, and comments made in that chapter also apply to the present comparisons. Finally, a summary of the observations covering predictions made by all four agencies is given in Table 5.8. It will be seen from comparison of Table 5.8 with Table 4.8 that the relationship of predictions to the data was almost the same for both events. The actual crater volume for this event was 166,000 cubic feet, as compared to 152,000 cubic feet for Event 1 and to 105,000 cubic feet predicted by AFWL.

Table 5.1. Pre-DICE THROW II, Event 2 Acceleration Data with Predictions and Deviations

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
12.2	0.5	V	0	-	-	2750.	2750.	-/-	10000.	-/-	-	-/-	-	-/-	-
12.2	0.5	H	0	-	-	-	-	-/-	5500.	-/-	-	-/-	-	-/-	-
12.2	1.8	V	0	2900.	2900.	-	-	-/-	10000.	-/-	-	-/-	-245.	-/-	-
12.2	1.8	H	0	2800.	2800.	-	-	-/-	4500.	-/-	-	-/-	-61.	-/-	-
18.3	0.5	V	0	790.	790.	800.	800.	-/-	2300.	-/-	-	-/-	-191.	-/-	-
18.3	0.5	H	0	89.	89.	-	-	-/-	1300.	-/-	-	-/-	-1361.	-/-	-
18.3	1.8	V	0	345.	345.	-	-	-/-	2000.	-/-	-	-/-	-480.	-/-	-
18.3	1.8	H	0	120.	120.	-	-	-/-	1100.	-/-	-	-/-	-817.	-/-	-
18.3	3.7	V	0	1800.	1800.	12000.**	12000.**	-/-	2000.	-/-	-	-/-	-11.1	-/-	-
18.3	3.7	H	0	-	-	-	-	-/-	1100.	-/-	-	-/-	-	-/-	-
18.3	6.1	V	0	*	*	*	*	-/-	2000.	-/-	-	-/-	-	-/-	-
18.3	6.1	H	0	3600.**	3600.**	-	-	-/-	1100.	-/-	-	-/-	69.	-/-	-
18.3	9.1	V	0	*	*	*	*	-/-	2000.	-/-	-	-/-	-	-/-	-
18.3	9.1	H	0	*	*	*	*	-/-	1100.	-/-	-	-/-	-	-/-	-
24.4	3.7	V	0	2200.	2200.	950.	950.	-/4.68	700.	-/-	-	-/99.5	68.	-/-	-
24.4	3.7	H	0	1350.	1350.	800.	800.	-/-	400.	-/-	-	-/-	70.	-/-	-
24.4	6.1	V	0	1900.**	1900.**	-	-	-/4.44	700.	-/-	-	-/-	63.	-/-	-
24.4	6.1	H	0	1400.	1400.	-	-	-/-	400.	-/-	-	-/-	71.	-/-	-
24.4	9.1	V	0	*	*	*	*	-/4.28	700.	-/-	-	-/-	-/-	-/-	-
24.4	9.1	H	0	1400.**	1400.**	-	-	-/-	400.	-/-	-	-/-	71.	-/-	-

Table 5.1. Pre-DICE THROW II, Event 2 Acceleration Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) g's	Average Direct Induced g's	Airblast Induced (Negative) g's	Average Airblast Induced g's	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
33.5	3.7	V	0	760.		-									
33.5	3.7	V	120	*	760.	-	500.**	-/-	200.	-/-	-	-/	74.	-/-	-
33.5	3.7	V	240	700.**		500.**									
33.5	3.7	H	0	360.**		-									
33.5	3.7	H	120	380.**	357.**	-	-	-/-	150.	-/-	-	-/-	58.	-/-	-
33.5	3.7	H	240	330.**		-									
33.5	6.1	V	0	850.		-									
33.5	6.1	V	120	320.	585.	350.	420.	-/-	200.	-/-	-	-/-	66.	-/-	-
33.5	6.1	V	240	810.**		490.									
33.5	6.1	H	0	280.**		-									
33.5	6.1	H	120	370.**	353.**	-	-	-/-	150.	-/-	-	-/-	58.	-/-	-
33.5	6.1	H	240	410.**		-									

* No peak data
** Out of band

Table 5.2. Pre-DICE THROW II, Event 2 Velocity Data with Predictions and Deviations

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
24.4	0.5	V	0	4.3	4.3	5.0	5.0	3.1/5.5	5.49	3.05/3.96	3.05	29.1/-9.2	-27.7	29.1/20.8	29.1
24.4	0.5	H	0	2.4	2.4	-	-	3.17/-	3.51	2.38/-	1.52	-32.1/-	-46.3	0.8/-	36.7
24.4	1.8	V	0	2.6	2.5	0.72	0.72	-/-	3.66	1.68/0.94	-	-/-	-40.8	35.4/-30.6	-
24.4	1.8	H	0	2.4	2.4	0.62	0.62	-/-	3.51	2.19/-	-	-/-	-46.3	8.8/-	-
33.5	0.5	V	0	2.7		4.0									
33.5	0.5	V	120	2.4	2.53	3.9	4.0	-/-	3.05	1.37/3.20	-	-/-	-16.0	47.9/19.4	-
33.5	0.5	V	240	2.8		4.0									
33.5	0.5	H	0	0.39/0.94		0.49									
33.5	0.5	H	120	1.2	0.86	0.55	0.58	-/-	1.83	1.22/-	-	-/-	-113.	-41.9/-	-
33.5	0.5	H	240	0.5/0.9		0.70									
33.5	1.8	V	0	0.92	0.32	0.64	0.64	-/-	2.13	1.01/0.82	-	-/-	-132.	-9.8/-28.1	-
33.5	1.8	H	0	0.90	0.30	-	-	-/-	1.83	1.19/-	-	-/-	-103.	-32.2/-	-
33.5	9.1	V	0	0.72	0.72	-	-	-/-	-	-/-	-	-/-	-	-/-	-
33.5	9.1	H	0	1.0	1.0	-	-	-/-	-	-/-	-	-/-	-	-/-	-
39.6	0.5	V	0	-	-	-	-	-/-	-	-/-	-	-/-	-	-/-	-
39.6	0.5	H	0	0.52	0.52	0.38	0.38	-/-	-	-/-	-	-/-	-	-/-	-
48.8	0.5	V	0	1.70		3.75									
48.8	0.5	V	120	1.40	1.33	2.60	3.82	0.98/4.7	1.52	0.76/1.83	1.52	26.3/-23.6	-14.3	42.9/52.1	-14.3
48.8	0.5	V	240	0.90		5.10									
48.8	0.5	H	0	0.2		0.07									
48.8	0.5	H	120	0.46	0.31	0.24	0.16	1.01/-	.82	0.59/-	0.61	-225/-	-165.	-90.3/-	-96.8
48.8	0.5	H	240	0.23/0.32		0.17									
48.8	1.8	V	0	0.70		1.60									
48.8	1.8	V	120	0.43	0.54	0.49	1.23	-/-	1.07	0.56/0.67	-	-/-	-98.1	-3.7/45.5	-
48.8	1.8	V	240	0.50		1.60									

Table 5.2. Pre-DICE THROW II, Event 2 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
48.8	1.8	H	0	0.52		0.31									
48.8	1.8	H	120	0.48	0.44	0.20	0.22	-/-	0.82	0.58/-	-	-/-	-86.4	-31.8/-	-
48.8	1.8	H	240	0.33		0.14									
48.8	3.7	V	0	0.31		0.14									
48.8	3.7	V	120	0.33	0.34	0.16	0.27	1.14/0.4	0.76	0.43/0.40	0.30	-235./-48.	-124.	-26.5/-48.1	11.8
48.8	3.7	V	240	0.37		0.52									
48.8	3.7	H	0	0.33		0.29									
48.8	3.7	H	120	0.42	0.35	0.25	0.25	1.13/-	0.82	0.55/-	0.61	-29.6/-	-204.	-104./-	-74.3
48.8	3.7	H	240	0.30		0.20									
48.8	6.1	V	0	0.33	0.33	0.15	0.15	-/0.40	0.49	0.37/0.29	-	-/-167.	-485	-12.1/-93.3	-
48.8	6.1	H	0	-	-	-	-	1.13/-	0.82	0.49/-	-	-/-	-	-/-	-
48.8	9.1	V	0	0.40	0.40	0.12	0.12	-/0.37	0.30	0.23/0.24	-	-/-208.	25.0	42.5/-100.	-
48.8	9.1	H	0	0.52	0.52	0.26	0.26	1.13/-	0.82	0.44/-	-	-117./-	-57.7	15.4/-	-
57.8	0.5	V	0	0.90	0.90	2.5	2.5	-/-	-	-/-	-	-/-	-	-/-	-
57.8	0.5	H	0	-	-	-	-	-/-	-	-/-	-	-/-	-	-/-	-
70.1	0.5	V	0	0.75		2.1									
70.1	0.5	V	120	0.70	0.68	2.1	2.1	0.53/2.1	0.76	0.38/1.07	-	22.1/1.4	-11.8	44.1/49.0	-
70.1	0.5	V	240	0.60		2.0									
70.1	0.5	H	0	0.21		0.28									
70.1	0.5	H	120	0.18	0.19	0.19	0.20	0.55/-	0.43	0.35/-	-	-190/-	-126.	-84.2/-	-
70.1	0.5	H	240	0.18		0.12									
70.1	1.8	V	0	0.22	0.22	0.87	0.87	-/-	0.55	0.36/0.49	-	-/-	-150.	-63.0/43.7	-
70.1	1.8	H	0	0.23	0.23	0.18	0.18	-/-	0.43	0.36/-	-	-/-	-87.0	-47.8/-	-
70.1	3.7	V	0	0.17		0.12									
70.1	3.7	V	120	0.22	0.20	0.18	0.12	0.61/0.27	0.40	0.24/0.30	-	-205./-125.	-100.	-20.0/-150.	-
70.1	3.7	V	240	0.22		0.05									

Table 5.2. Pre-DICE THROW II, Event 2 Velocity Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) m/sec	Average Direct Induced (m/sec)	Airblast Induced (Negative) m/sec	Average Airblast Induced m/sec	Predictions, m/sec				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
70.1	3.7	H	0	0.33		0.19									
70.1	3.7	H	120	0.28	0.27	0.17	0.16	0.58/-	0.43	0.33/-	-	-115./-	-59.3	-22.2/-	-
70.1	3.7	H	240	0.19		0.11									
70.1	6.1	V	0	0.17	0.17	0.09	0.09	-/0.27	0.27	0.18/0.22	-	-/-200.	-58.8	-5.9/-144.	-
70.1	6.1	H	0	0.30	0.30	0.18	0.18	0.58/-	0.43	0.30/-	-	-93.3/-	-43.3	0.0/-	-
85.4	0.5	V	0	0.65	0.65	1.4	1.4	-/-	-	-/-	-	-/-	-	-/-	-
85.4	0.5	H	0	0.17	0.17	0.12	0.12	-/-	-	-/-	-	-/-	-	-/-	-
91.4	0.5	V	0	0.40	0.40	1.1	1.1	0.30/1.2	0.49	25./-5.5	-	-/-5.5	-22.5	42.5/44.5	-
91.4	0.5	H	0	0.36	0.36	0.08	0.08	0.34/-	0.21	0.25/-	-	5.6/-	41.7	30.6/-	-
97.7	0.5	V	0	0.37	0.37	0.71	0.71	-/-	-	-/-	-	-/-	-	-/-	-
97.7	0.5	H	0	0.13	0.13	0.11	0.11	-/-	-	-/-	-	-/-	-	-/-	-
106.6	0.5	V	0	0.18	0.18	0.40	0.40	-/-	-	-/-	-	-/-	-	-/-	-
106.6	0.5	H	0	0.13	0.13	0.08	0.08	-/-	-	-/-	-	-/-	-	-/-	-
121.9	0.5	V	0	0.12	0.12	0.42	0.42	0.18/0.58	0.40	0.18/0.37	-	-50./-38.	-233.	-50.0/11.9	-
121.9	0.5	H	0	0.13	0.13	0.5	0.5	0.18/-	0.18	0.18/-	-	-38.5/-	-38.5	-38.5/-	-
121.9	1.8	V	0	0.10	0.10	0.08	0.08	-/-	0.30	0.16/0.25	-	-/-	-200.	-60.0/-205.	-
121.9	1.8	H	0	0.20	0.20	0.07	0.07	-/-	0.14	0.17/-	-	-/-	30.0	15.0/-	-
121.9	3.7	V	0	0.12	0.12	0.09	0.09	0.23/0.09	0.22	0.10/0.19	-	-91./-5.9	-83.3	16.7/-124.	-
121.9	3.7	H	0	0.21	0.21	0.07	0.07	0.21/-	0.12	0.16/-	-	0.0/-	42.9	23.8/-	-
121.9	6.1	V	0	0.12	0.12	0.09	0.09	-/0.09	0.15	0.06/0.14	-	-/-2.3	-25.0	50.0/-59.1	-
121.9	6.1	H	0	0.17	0.17	0.07	0.07	0.21/-	0.12	0.14/-	-	-23.5/-	29.4	17.6/-	-

Table 5.3. Pre-DICE THROW II, Event 2 Displacement Data with Predictions and Deviations

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
24.4	0.5	V	0	75.	75.	-	-	145./5.1	-	64./4.3	-	-93./-	-	14.7/-	-
24.4	0.5	H	0	72.	72.	-	-	132./-	-	85.3/-	-	-83.5/-	-	-18.5/-	-
24.4	1.8	V	0	80.	80.	-	-	-/-	-	57.9/1.0	-	-/-	-	27.6/-	-
24.4	1.8	H	0	65.	65.	-	-	-/-	-	82.3/-	-	-/-	-	-26.6/-	-
33.5 33.5 33.5	0.5 0.5 0.5	V V V	0 120 240	33. 24. 25.	27.	- 4.2 4.6	4.4	-/-	-	24.1/4.3	-	-/-	-	11.4/2.3	-
33.5 33.5 33.5	0.5 0.5 0.5	H H H	0 120 240	31. 33 15.	26.	- - -	-	-/-	-	36.6/-	-	-/-	-	-39.7/-	-
33.5	1.8	V	0	-	-	-	-	-/-	-	23.2/1.4	-	-/-	-	-/-	-
33.5	1.8	H	0	-	-	-	-	-/-	-	33.5/-	-	-/-	-	-/-	-
33.5	9.1	V	0	-	-	-	-	-/-	-	21.3/0.30	-	-/-	-	-/-	-
33.5	9.1	H	0	-	-	-	-	-/-	-	25.6/-	-	-/-	-	-/-	-
39.6	0.5	V	0	-	-	-	-	-/-	-	-/-	-	-/-	-	-/-	-
39.6	0.5	H	0	14.	14.	-	-	-/-	-	-/-	-	-/-	-	-/-	-
48.8 48.8 48.8	0.5 0.5 0.5	V V V	0 120 240	7.0 6.5 6.5	6.7	5.6 3.5 5.8	5.0	18.1/4.3	-	7.0/3.0	-	-170./14.	-	-4.5/40.0	-
48.8 48.8 48.8	0.5 0.5 0.5	H H H	0 120 240	6.3 11.5 7.8	8.5	- - -	-	16.5/-	-	11.9/-	-	94.1/-	-	-40.0/-	-
48.8 48.8 48.8	1.8 1.8 1.8	V V V	0 120 240	3.5 6.9 4.1	4.8	1.9 - 2.0	1.9	-/-	-	6.7/1.4	-	-/-	-	-39.6/26.3	-

Table 5.3. Pre-DICE THROW II, Event 2 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
48.8	1.8	H	0	9.1		-									
48.8	1.8	H	120	12.0	9.4	-	-	-/-	-	11.6/-	-	-/-	-	-23.4/-	-
48.8	1.8	H	240	7.2		-									
48.8	3.7	V	0	3.2		-									
48.8	3.7	V	120	5.0	4.0	-	0.4	7.3/0.8	-	6.4/0.7	-	-91./-100.	-	-60.0/-75.0	-
48.8	3.7	V	240	3.8		0.4									
48.8	3.7	H	0	6.5		-									
48.8	3.7	H	120	9.8	7.8	-	-	7.4/-	-	11.0/-	-	5.1/-	-	-41.0/-	-
48.8	3.7	H	240	7.0		-									
48.8	6.1	V	0	2.4	2.4	-	-	3.5/0.8	-	5.8/0.4	-	-45./-	-	-142./-	-
48.8	6.1	H	0	-	-	-	-	3.6/-	-	9.0/-	-	-/-	-	-/-	-
48.8	9.1	V	0	1.5	1.5	-	-	1.5/0.8	-	5.5/0.3	-	0.0/-	-	-267./-	-
48.8	9.1	H	0	4.5	4.5	-	-	1.5/-	-	7.9/-	-	66.7/-	-	-75.6/-	-
57.8	0.5	V	0	4.0	4.0	3.9	-	-/-	-	-/-	-	-/-	-	-/-	-
57.8	0.5	H	0	-	-	-	-	-/-	-	-/-	-	-/-	-	-/-	-
70.1	0.5	V	0	3.4		4.3									
70.1	0.5	V	120	2.5	3.5	2.9	3.4	5.5/3.2	-	2.5/2.1	-	-58./5.9	-	28.6/38.2	-
70.1	0.5	V	240	4.5		2.9									
70.1	0.5	H	0	3.0		1.3									
70.1	0.5	H	120	2.6	2.9	-	1.3	5.6/-	-	4.3/-	-	-93.1/-	-	-48.3/-	-
70.1	0.5	H	240	3.0		-									
70.1	1.8	V	0	1.1	1.1	0.5	0.5	-/-	-	2.1/0.9	-	-/-	-	-90.9/-80.0	-
70.1	1.8	H	0	2.3	2.3	0.7	0.7	-/-	-	0.40/-	-	-/-	-	-73.9/-	-
70.1	3.7	V	0	0.4		-									
70.1	3.7	V	120	1.1	0.7	-	-	2.5/0.51	-	1.9/0.6	-	-253./-	-	-171./-	-
70.1	3.7	V	240	0.7		-									

Table 5.3. Pre-DICE THROW II, Event 2 Displacement Data with Predictions and Deviations (Continued)

Transducer Location and Orientation				Direct Induced (Positive) cm	Average Direct Induced cm	Airblast Induced (Negative) cm	Average Airblast Induced cm	Predictions, cm				Percent Deviation			
Range (m)	Depth (m)	Orientation Vert. or Horiz.	Radial (deg)					AFWL DI/AI	WES DI	RDA DI/AI	FC DI	AFWL DI/AI	WES DI	RDA DI/AI	FC DI
70.1	3.7	H	0	2.7		0.8									
70.1	3.7	H	120	2.7	2.4	-	0.8	2.5/-	-	3.7/-	-	-4.17/-	-	-54.2/-	-
70.1	3.7	H	240	1.8		-									
70.1	6.1	V	0	0.9	0.9	0.12	0.12	-/0.51	-	1.7/0.4	-	-/-325.	-	-84.8/-233.	-
70.1	6.1	H	0	2.6	2.6	0.7	0.7	1.3/-	-	3.5/-	-	50.0/-	-	-34.6/-	-
85.4	0.5	V	0	3.7	3.7	1.9	1.9	-/-	-	-/-	-	-/-	-	-/-	-
85.4	0.5	H	0	1.8	1.8	0.7	0.7	-/-	-	-/-	-	-/-	-	-/-	-
91.4	0.5	V	0	1.8	1.8	1.4	1.4	-/0.19	-	1.2/1.4	-	-/86.4	-	31.4/0	-
91.4	0.5	H	0	3.2	3.2	-	-	2.5/-	-	3.5/-	-	21.9/-	-	-9.4/-	-
97.7	0.5	V	0	0.3	0.3	0.8	0.8	-/-	-	-/-	-	-/-	-	-/-	-
97.7	0.5	H	0	1.1	1.1	0.6	0.6	-/-	-	-/-	-	-/-	-	-/-	-
106.6	0.5	V	0	0.5	0.5	0.4	0.4	-/-	-	-/-	-	-/-	-	-/-	-
106.6	0.5	H	0	0.9	0.9	0.5	0.5	-/-	-	-/-	-	-/-	-	-/-	-
121.9	0.5	V	0	0.4	0.4	0.3	0.3	-/1.0	-	0.6/0.6	-	-/-233.	-	-57.9/-100.	-
121.9	0.5	H	0	0.7	0.7	0.3	0.3	0.8/-	-	1.1/-	-	-14.3/-	-	-57./-	-
121.9	1.8	V	0	0.6	0.6	0.3	0.3	-/-	-	0.5/0.5	-	-/-	-	-110./-61.3	-
121.9	1.8	H	0	0.9	0.9	0.5	0.5	-/-	-	1.0/-	-	-/-	-	-13.6/-	-
121.9	3.7	V	0	0.7	0.7	0.3	0.3	-/-	-	0.5/0.4	-	-/-	-	23.1/-33.3	-
121.9	3.7	H	0	0.9	0.9	0.5	0.5	0.5/-	-	0.9/-	-	44.4/-	-	0.0/-	-
121.9	6.1	V	0	0.6	0.6	0.4	0.4	-/-	-	0.4/0.3	-	-/-	-	32.2/21.1	-
121.9	6.1	H	0	1.0	1.0	0.6	0.6	0.3/-	-	0.9/-	-	68.4/-	-	5.3/-	-

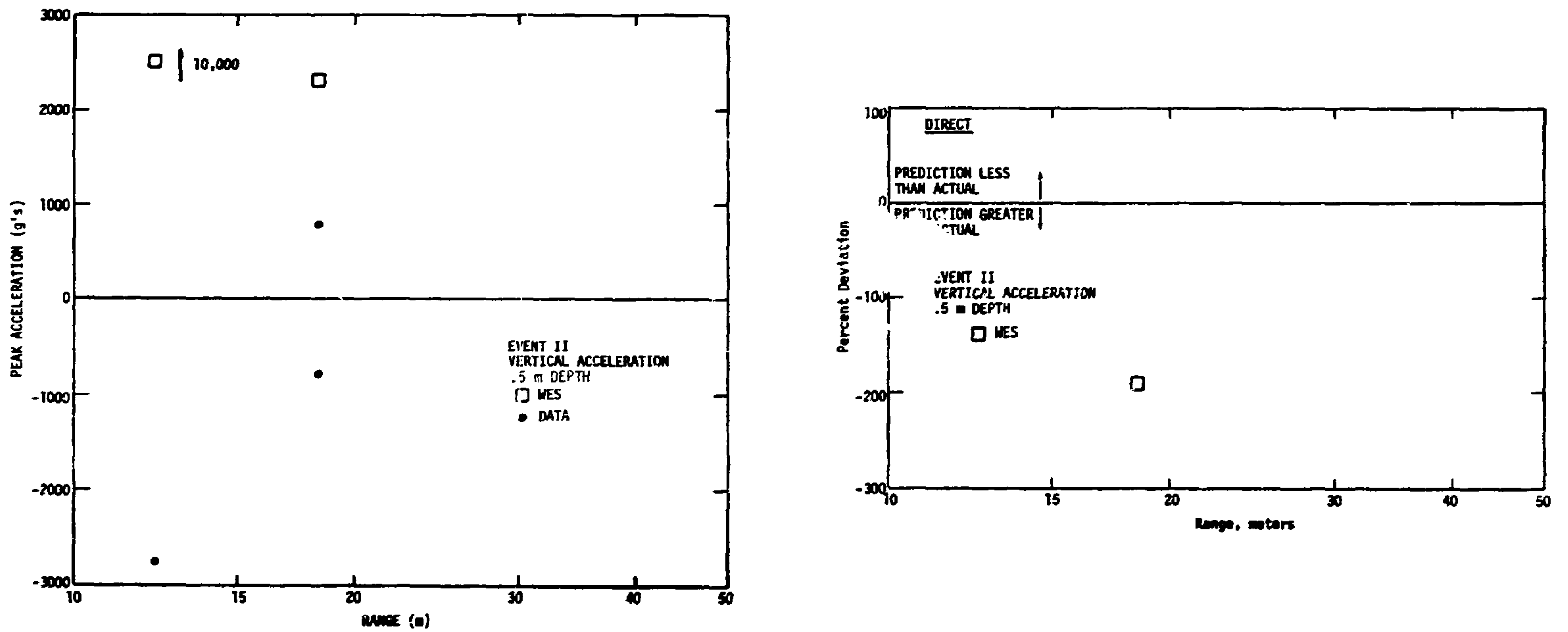


Figure 5.1. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

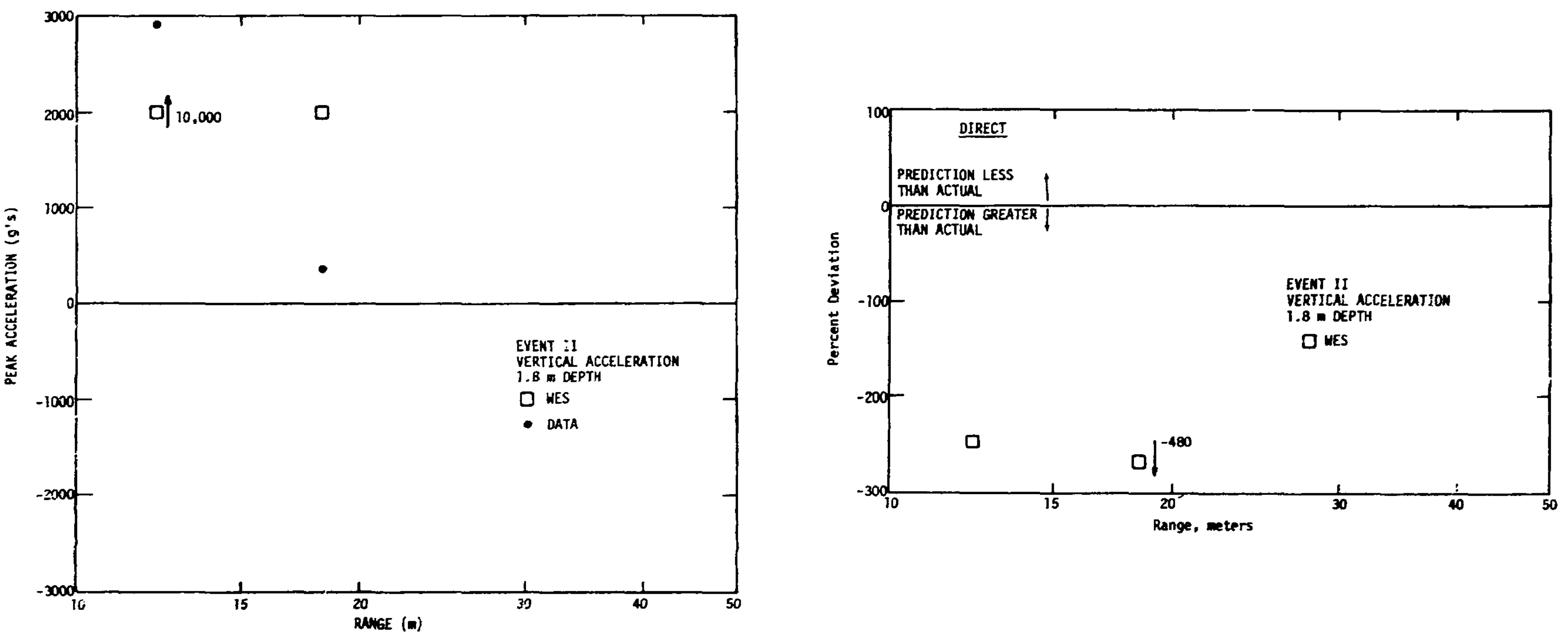


Figure 5.2. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

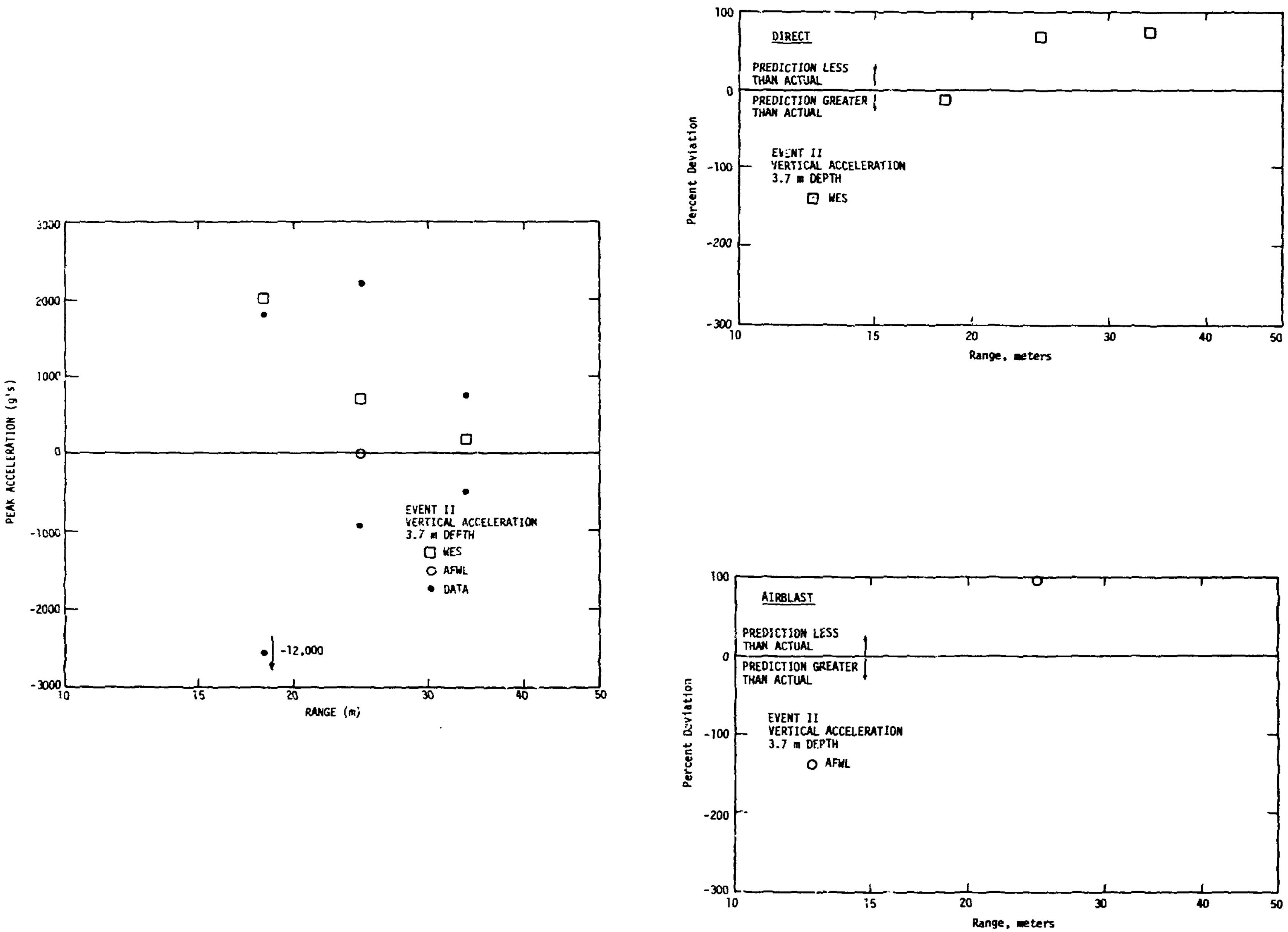


Figure 5.3. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

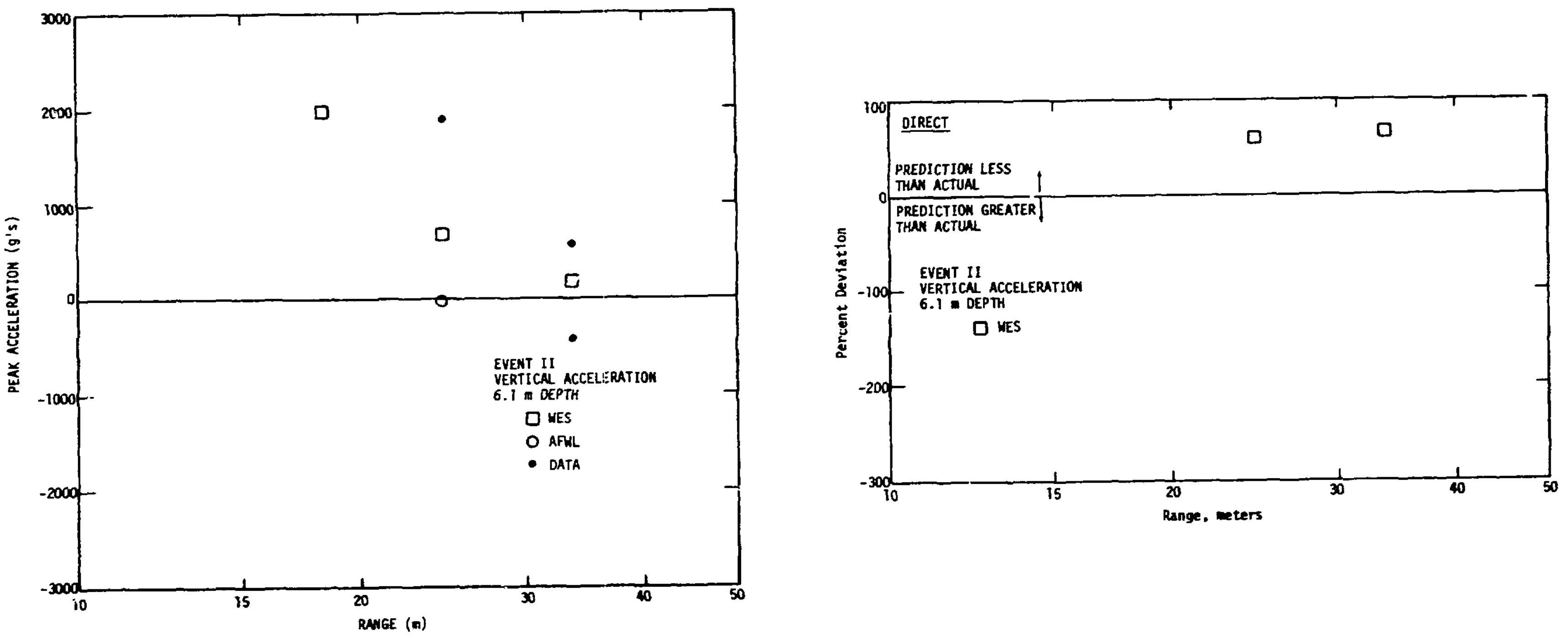


Figure 5.4. Vertical Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

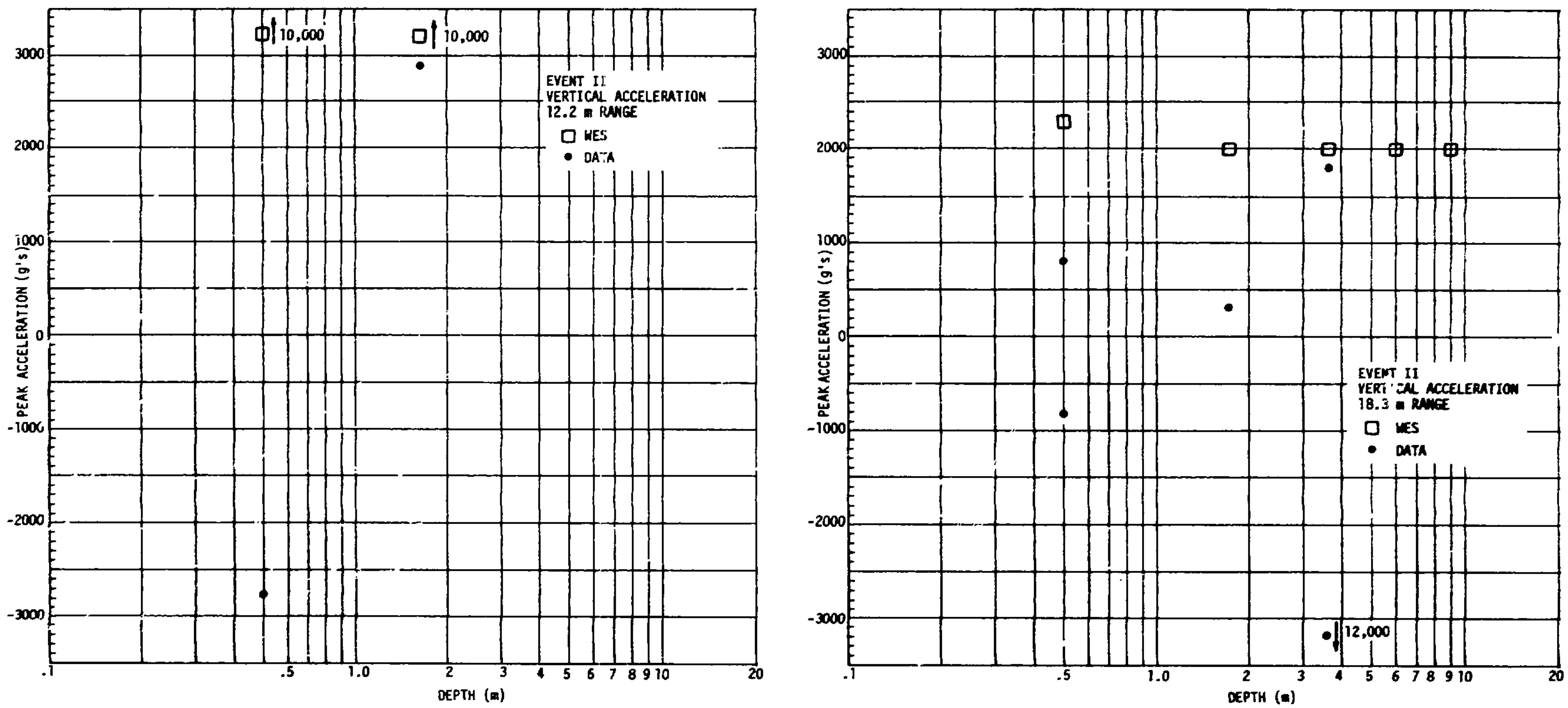


Figure 5.5. Vertical Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 2

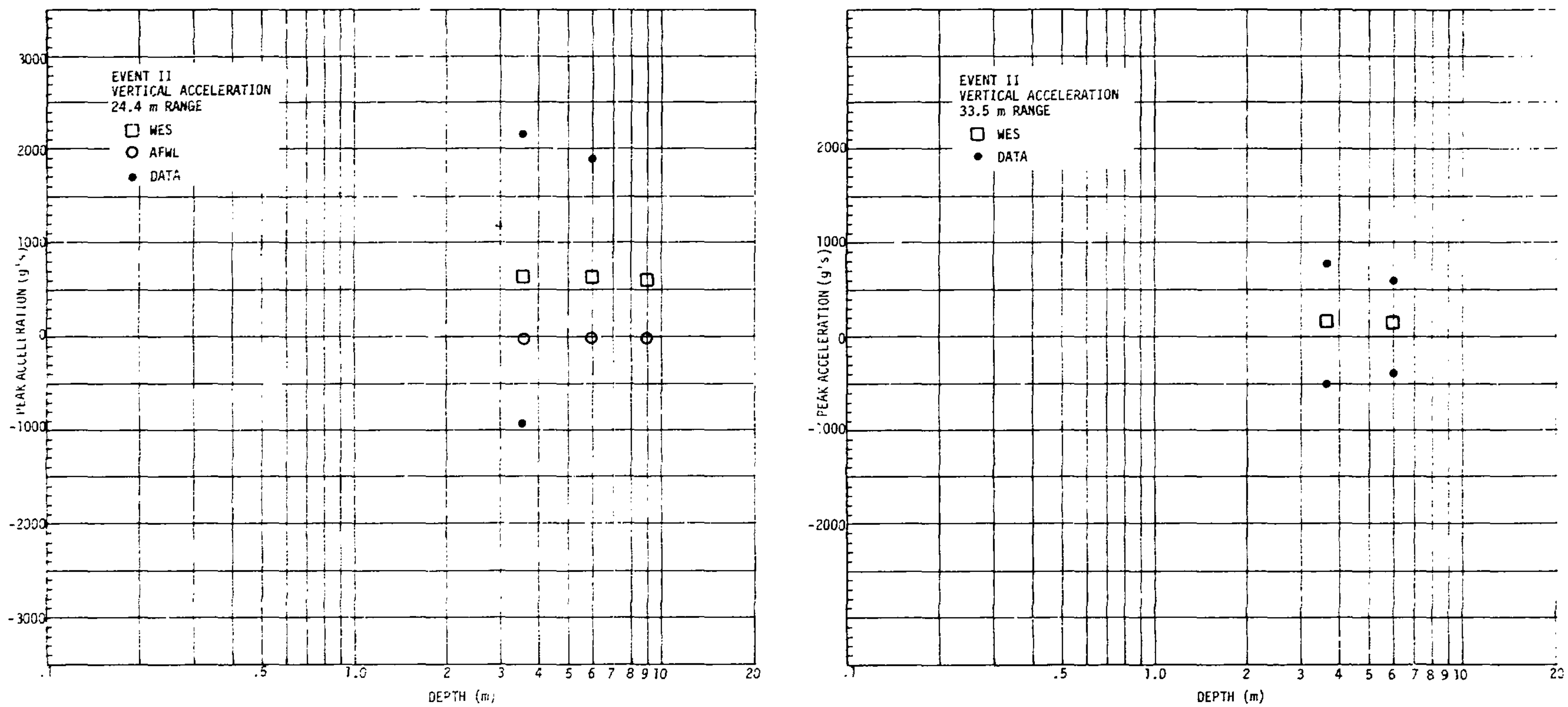


Figure 5.6. Vertical Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 2

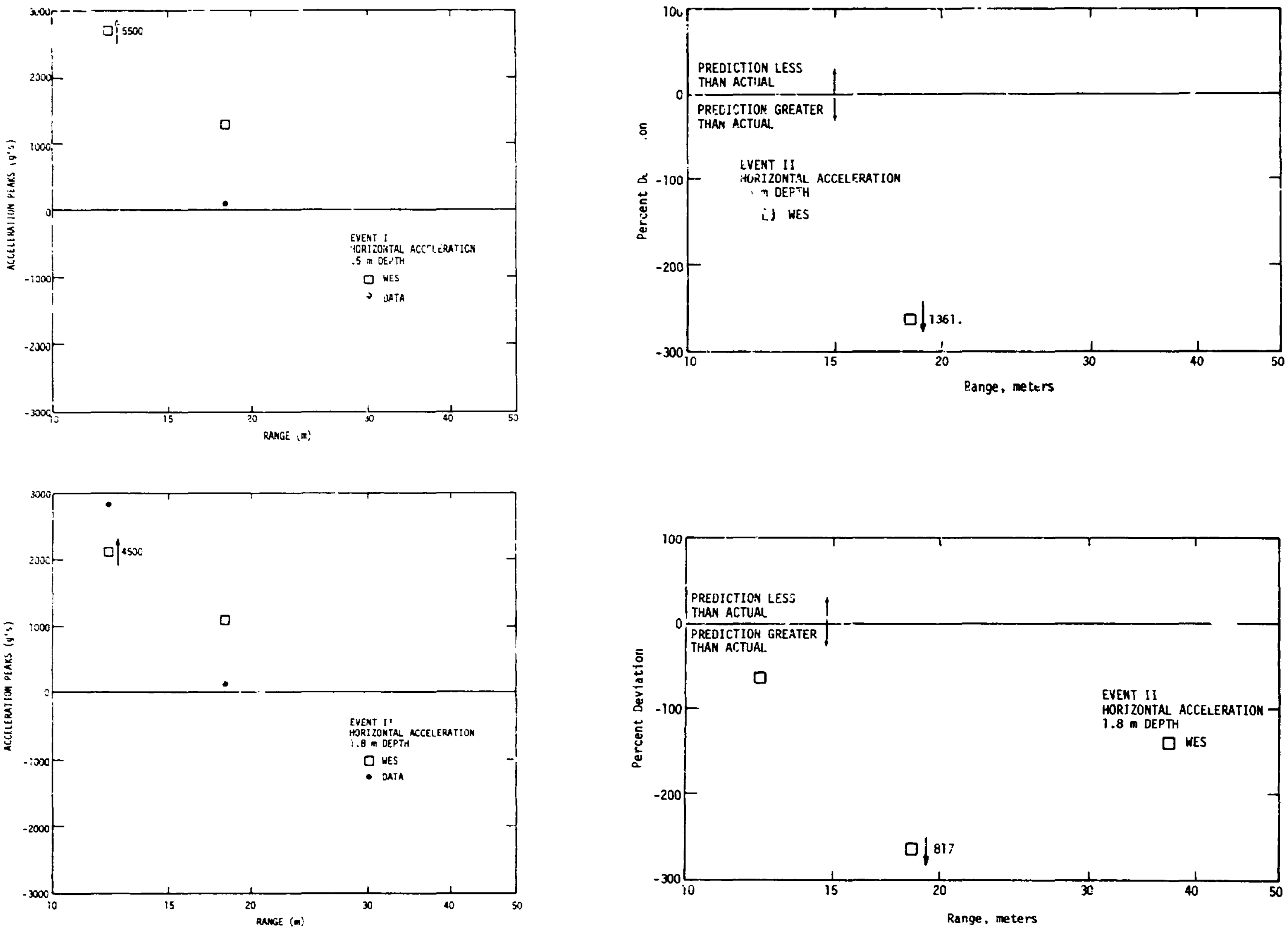


Figure 5.7. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

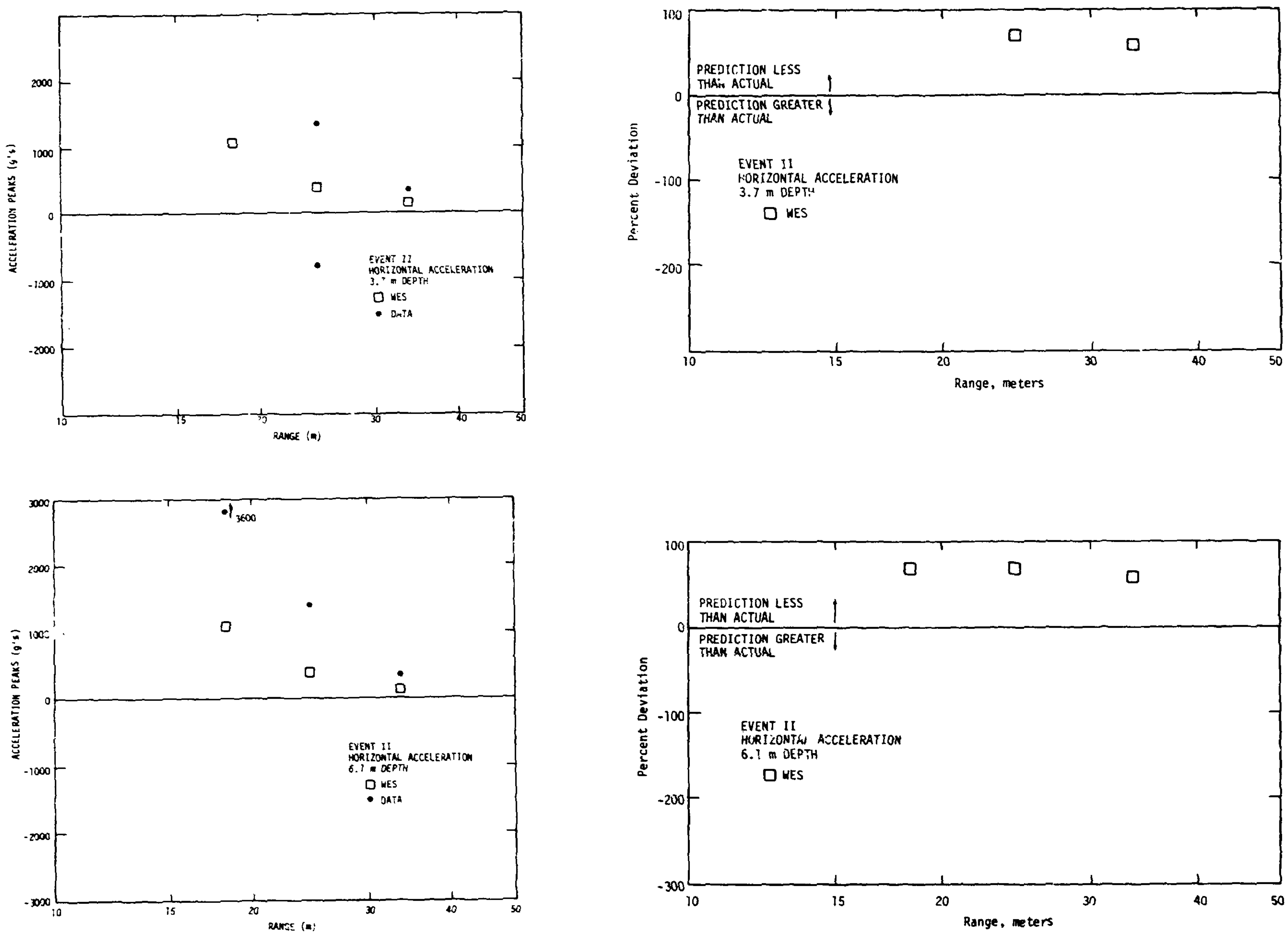


Figure 5.8. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

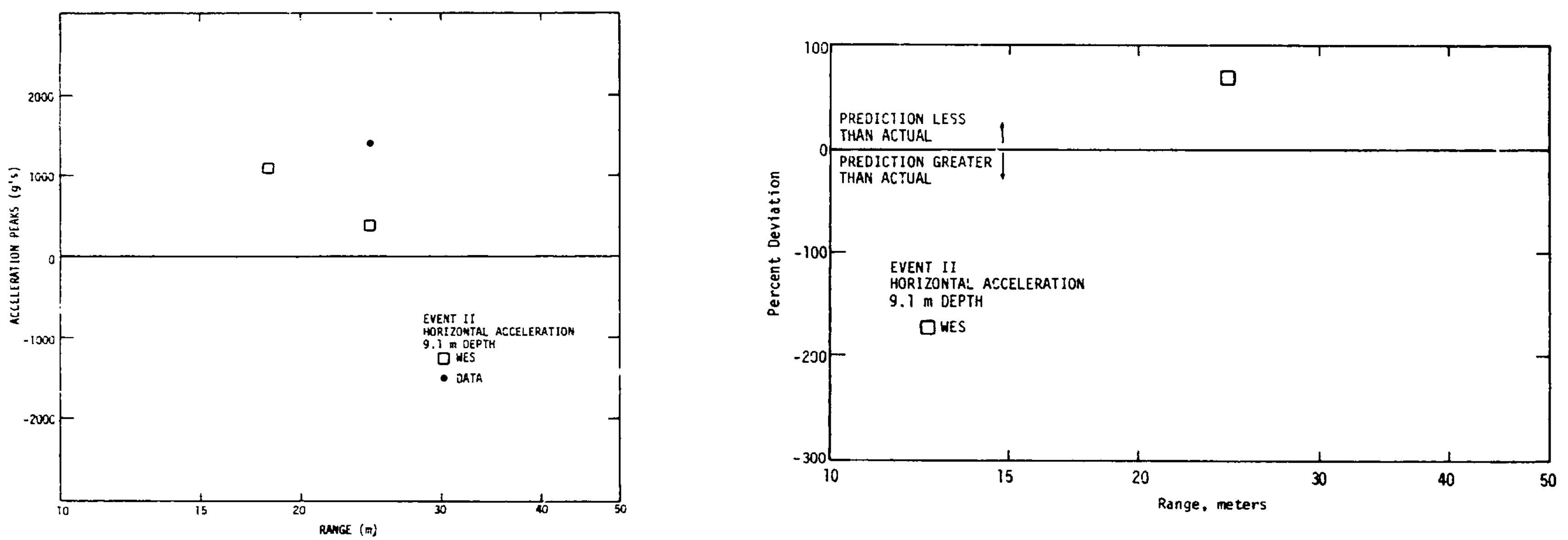


Figure 5.9. Horizontal Acceleration vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

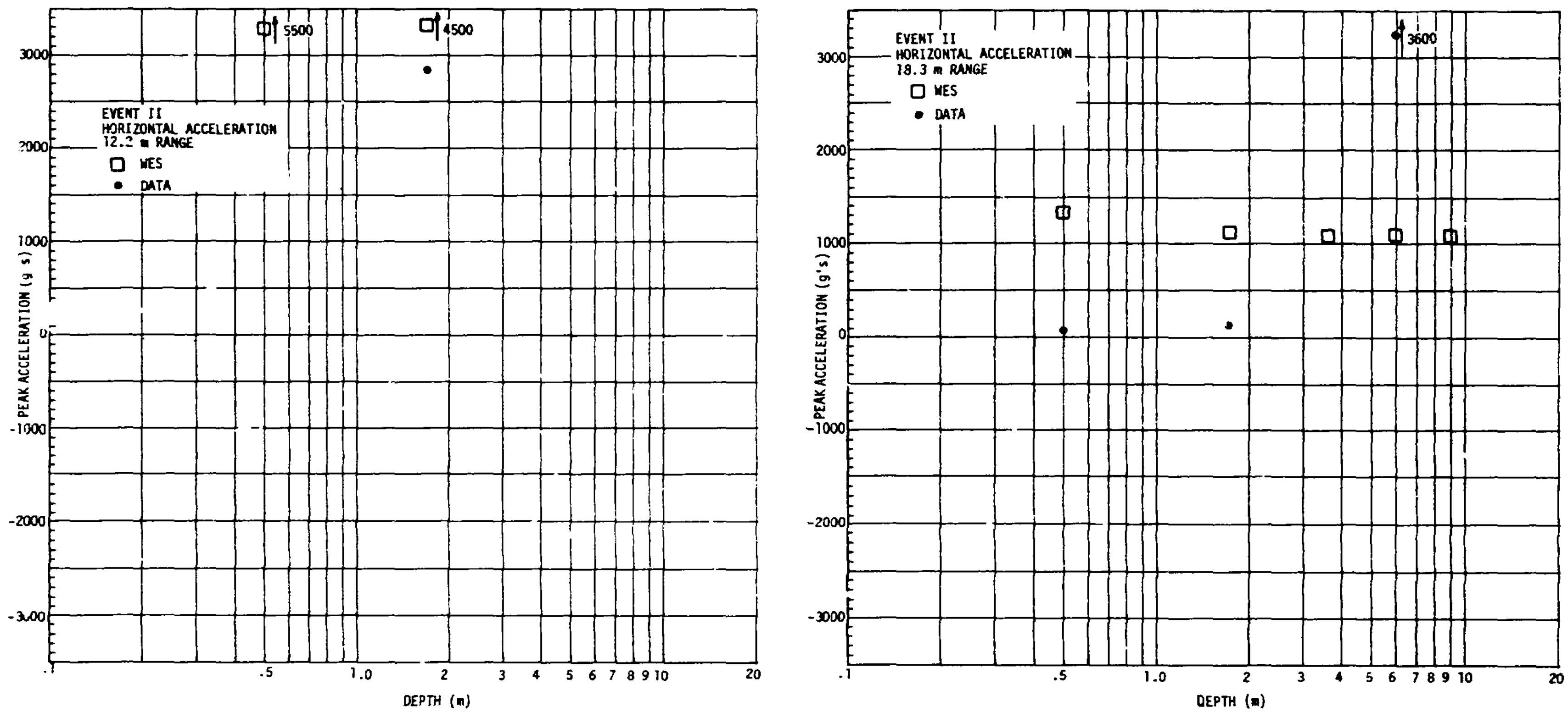


Figure 5.10. Horizontal Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 2

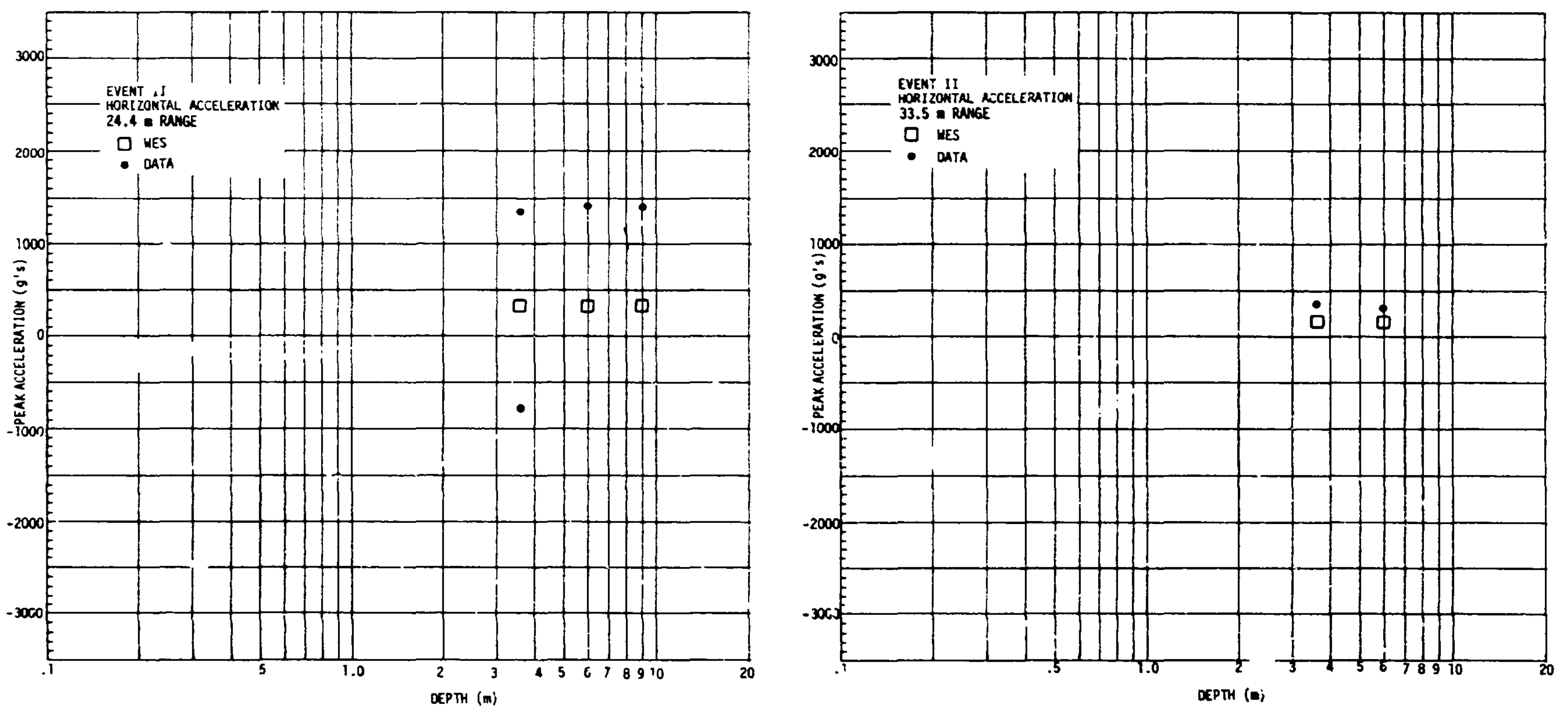


Figure 5.11. Horizontal Acceleration vs. Depth with Predictions for Pre-DICE THROW II, Event 2

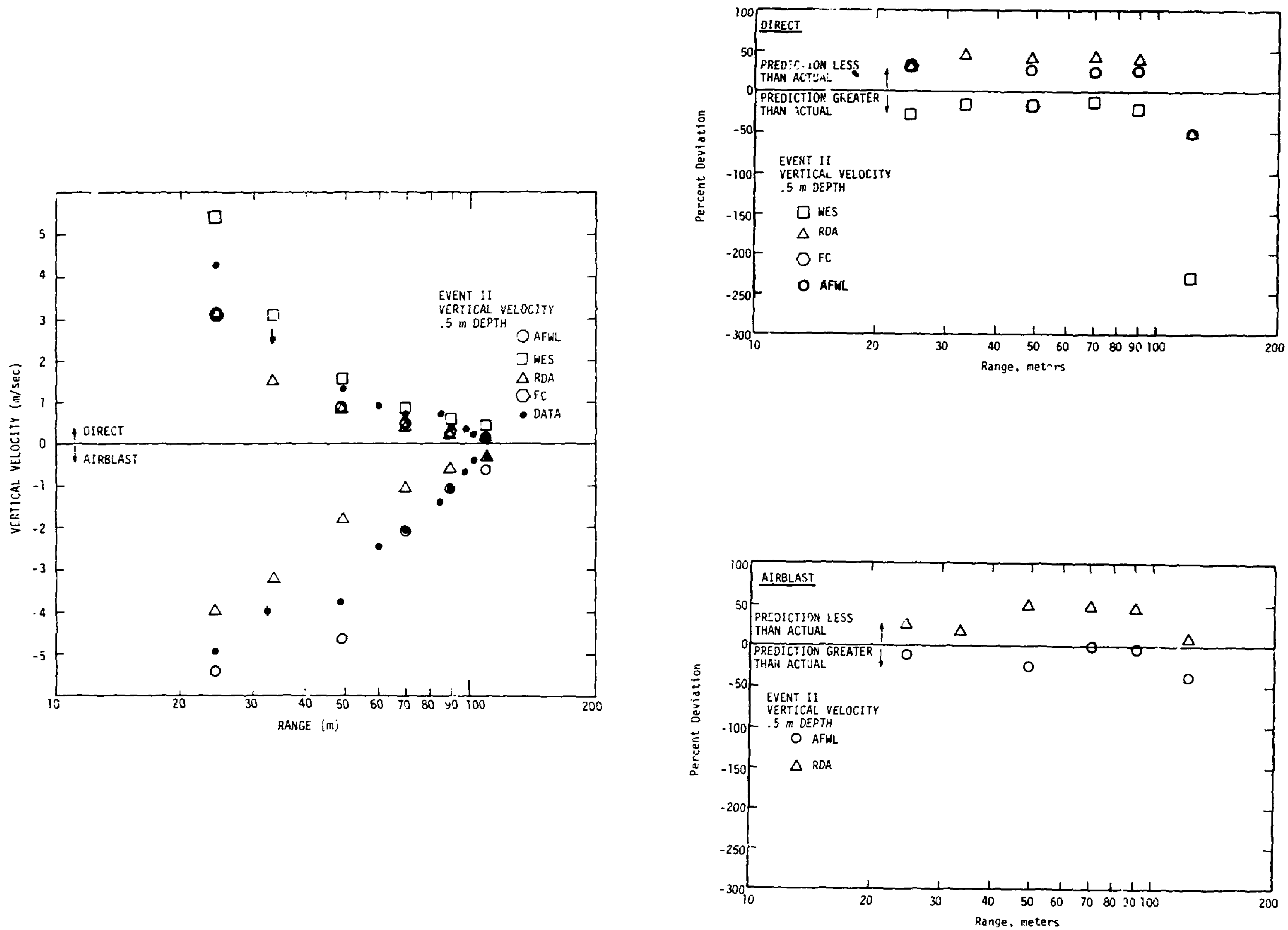


Figure 5.12. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

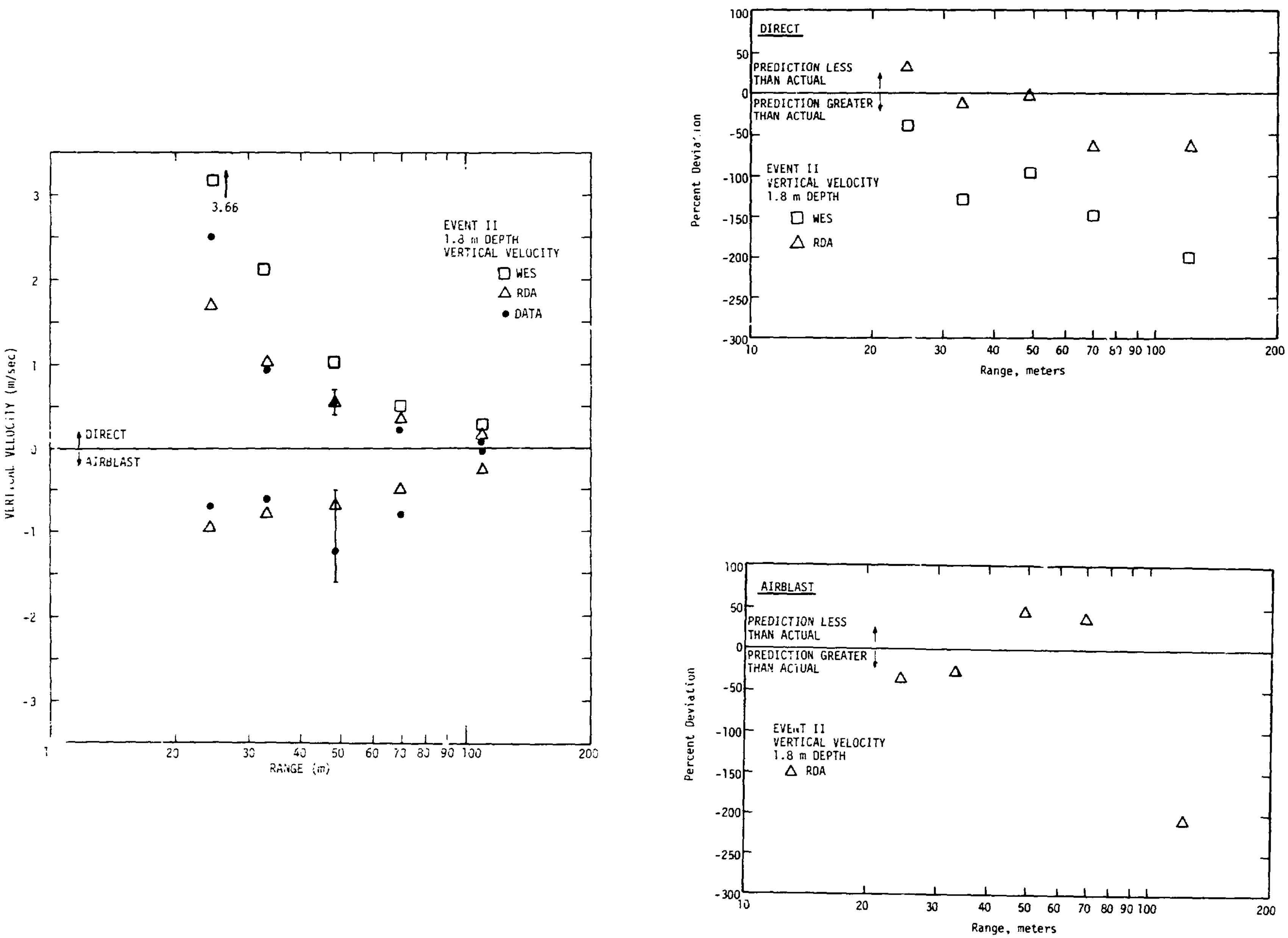


Figure 5.13. Vertical Velccity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

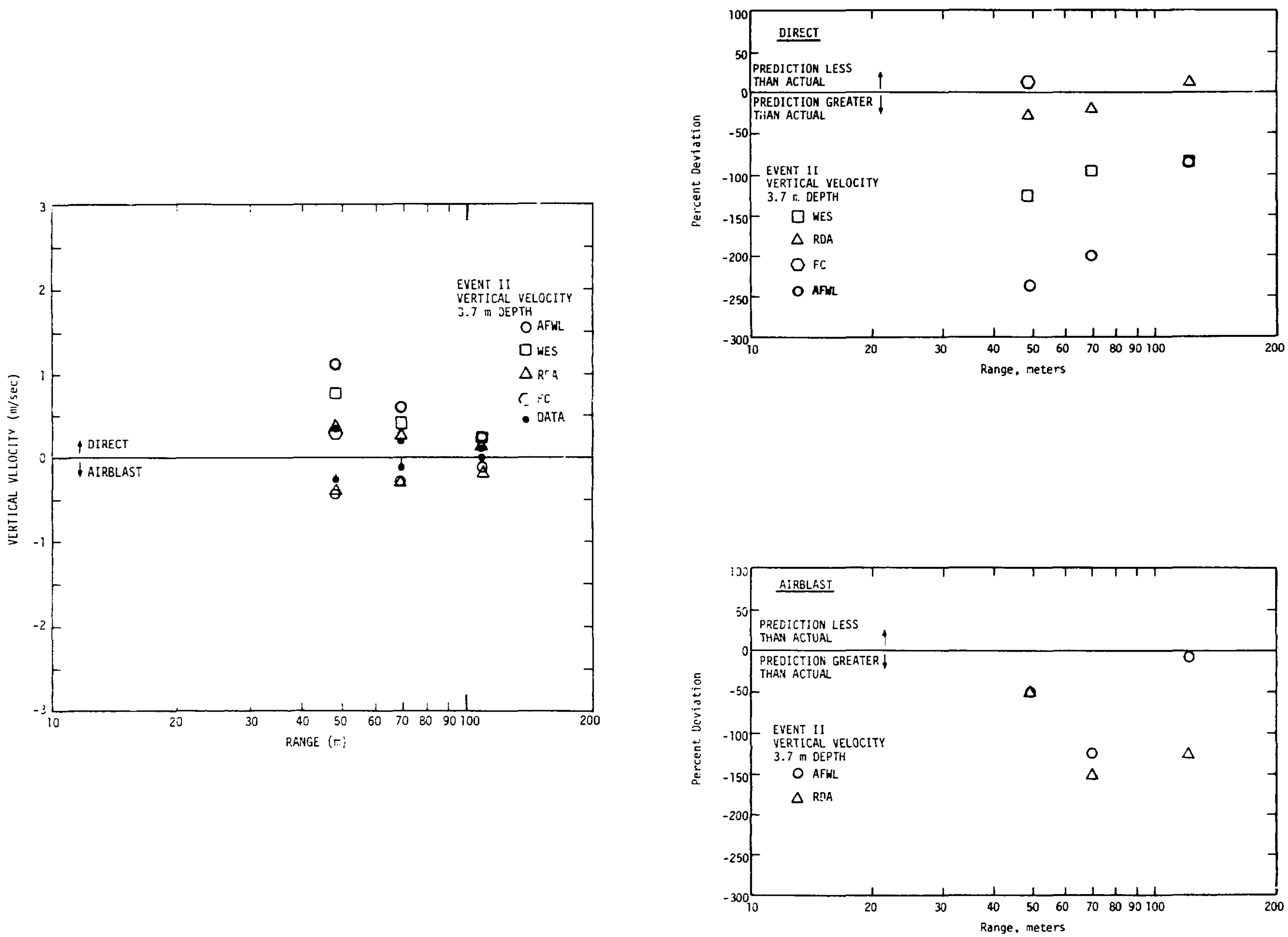


Figure 5.14. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

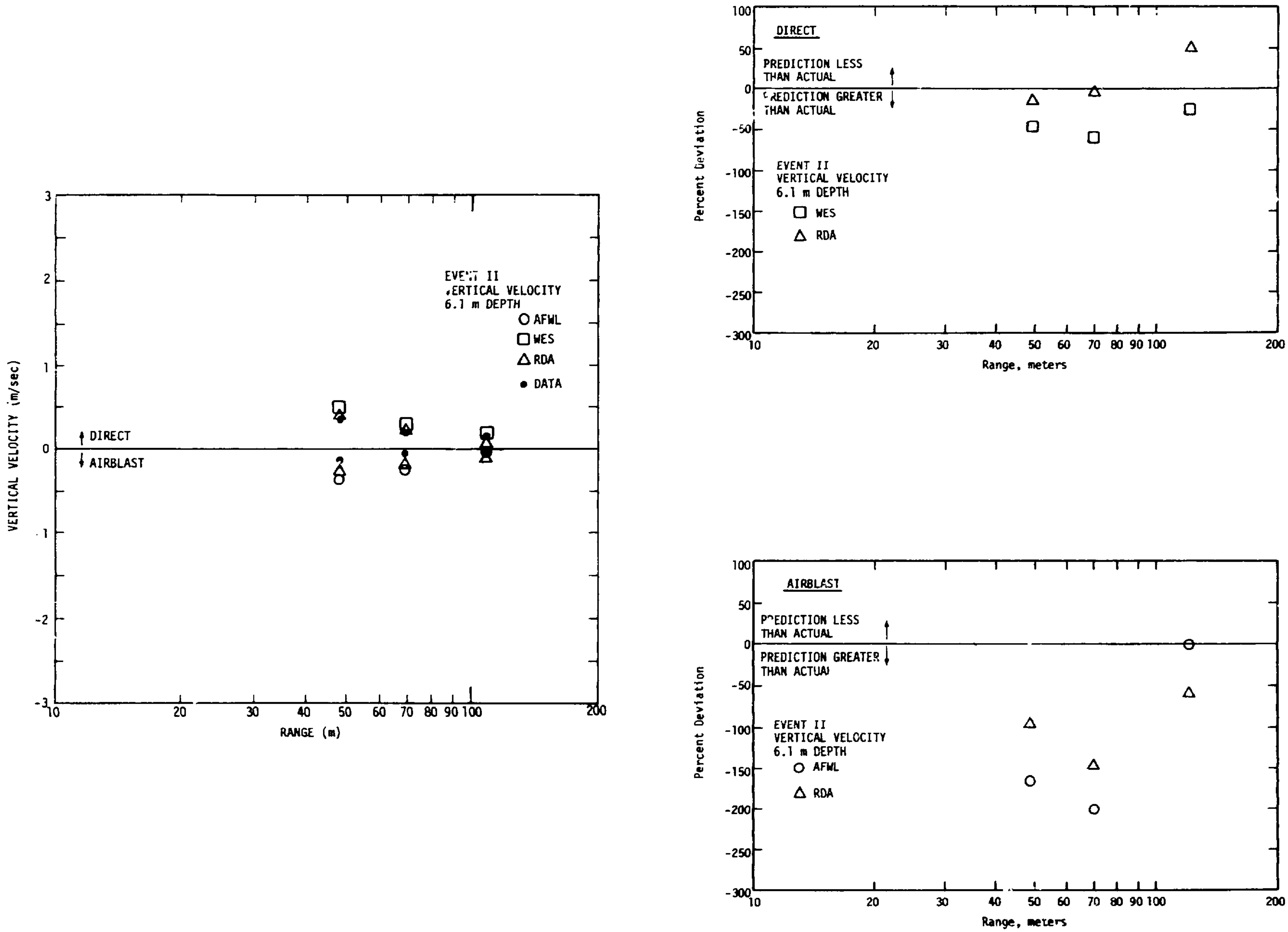


Figure 5.15. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

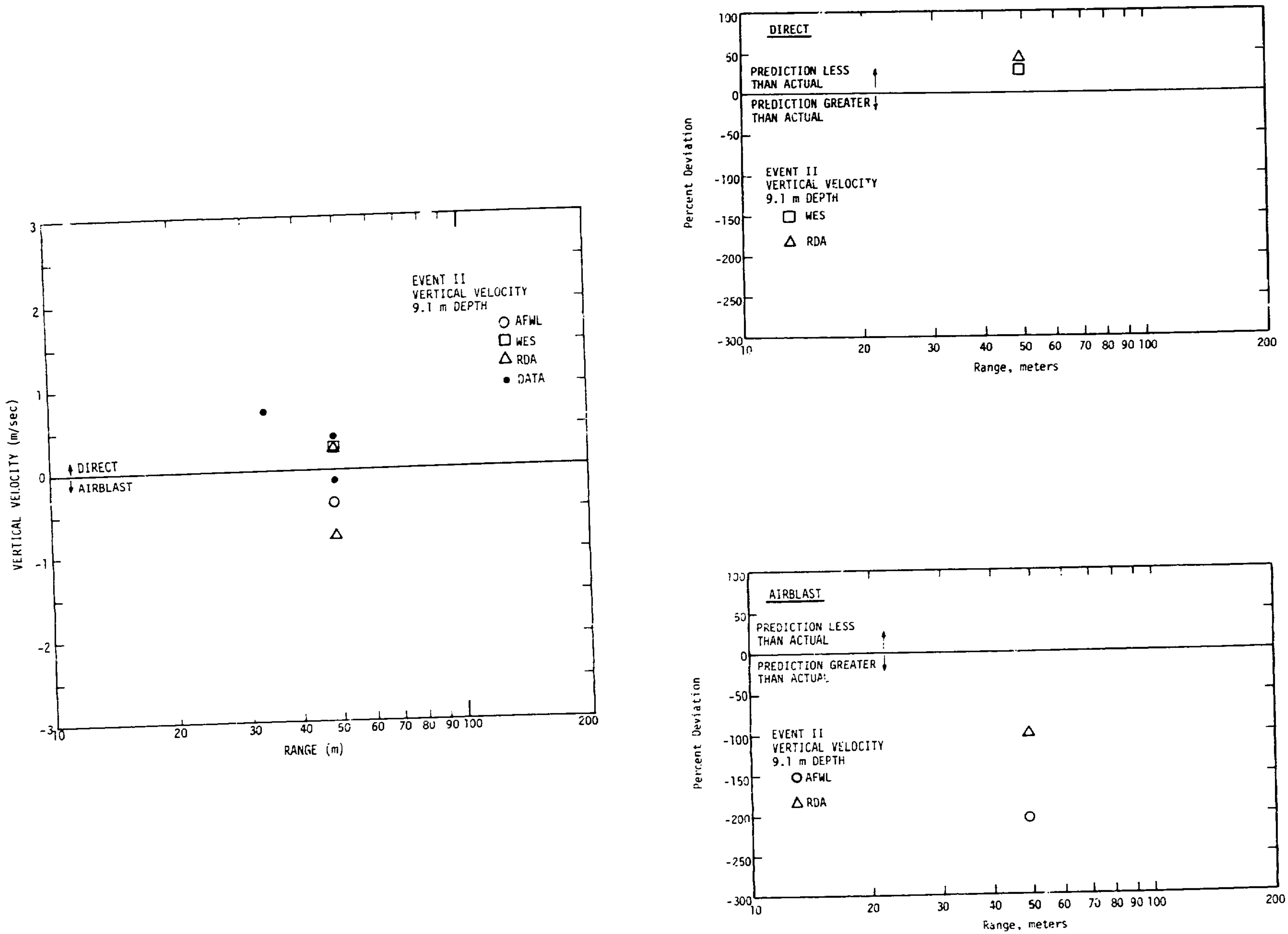


Figure 5.16. Vertical Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

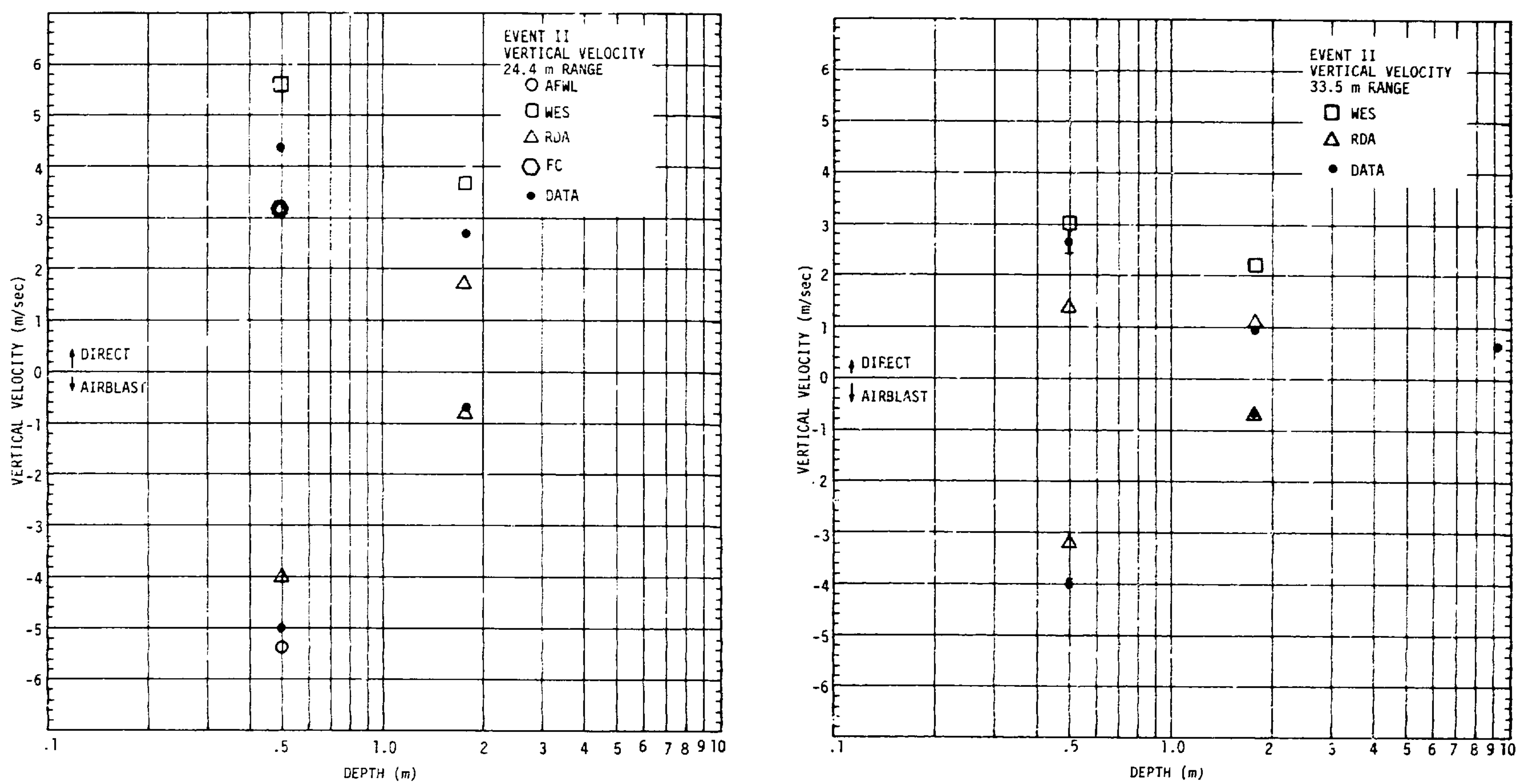


Figure 5.17. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 2

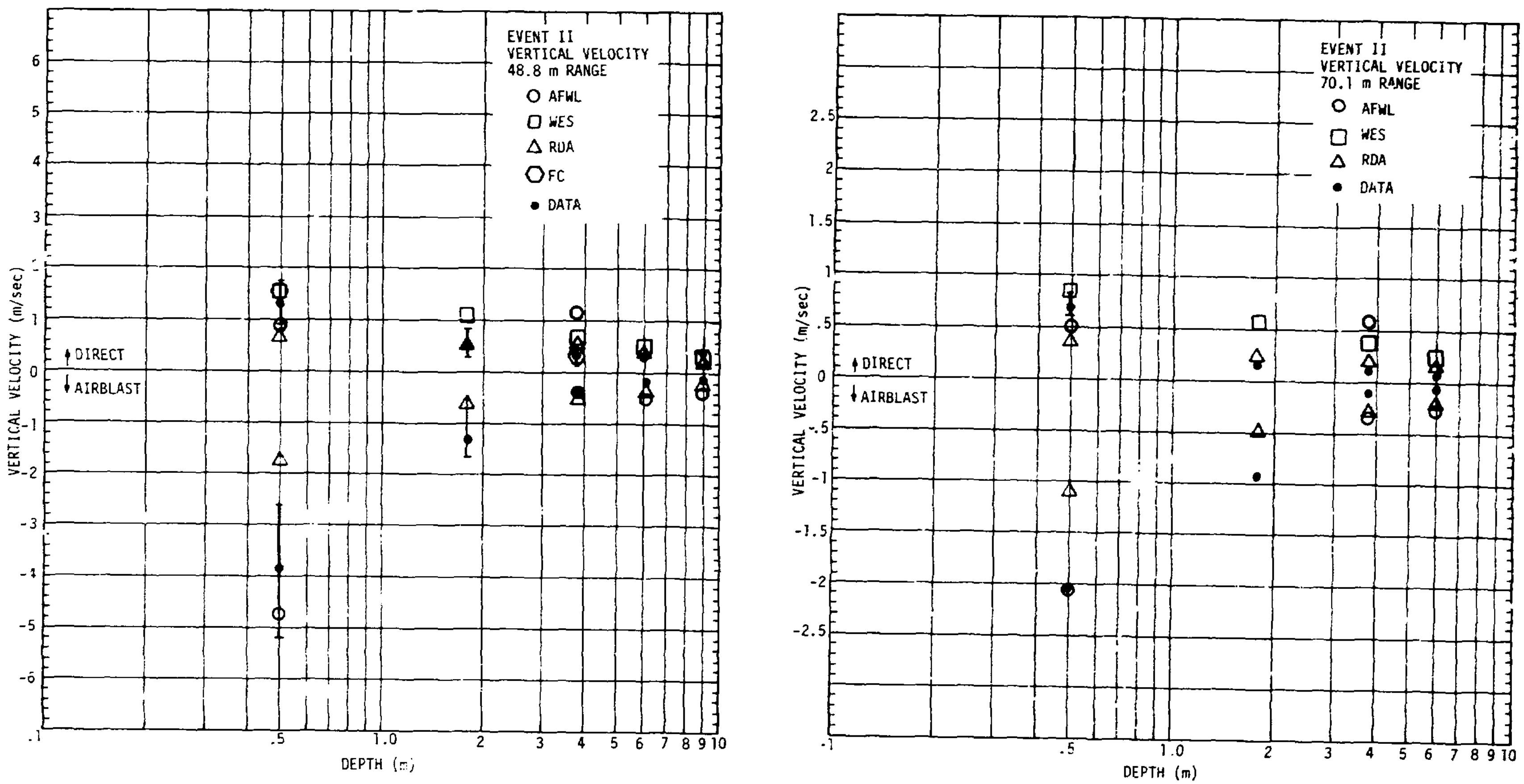
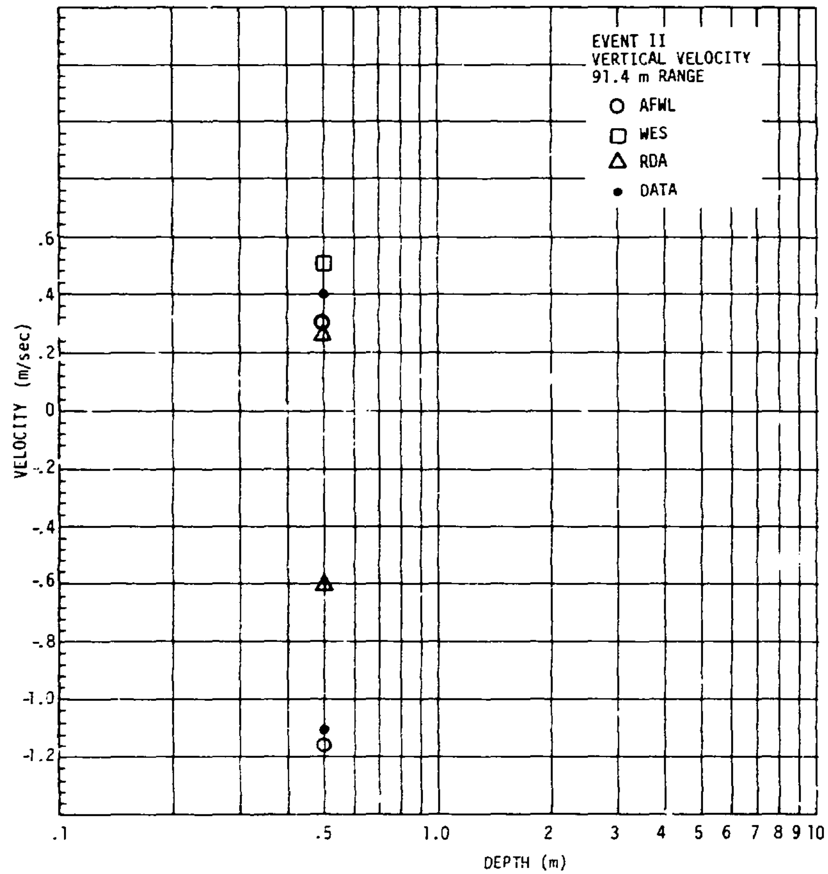


Figure 5.18. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II Event 2



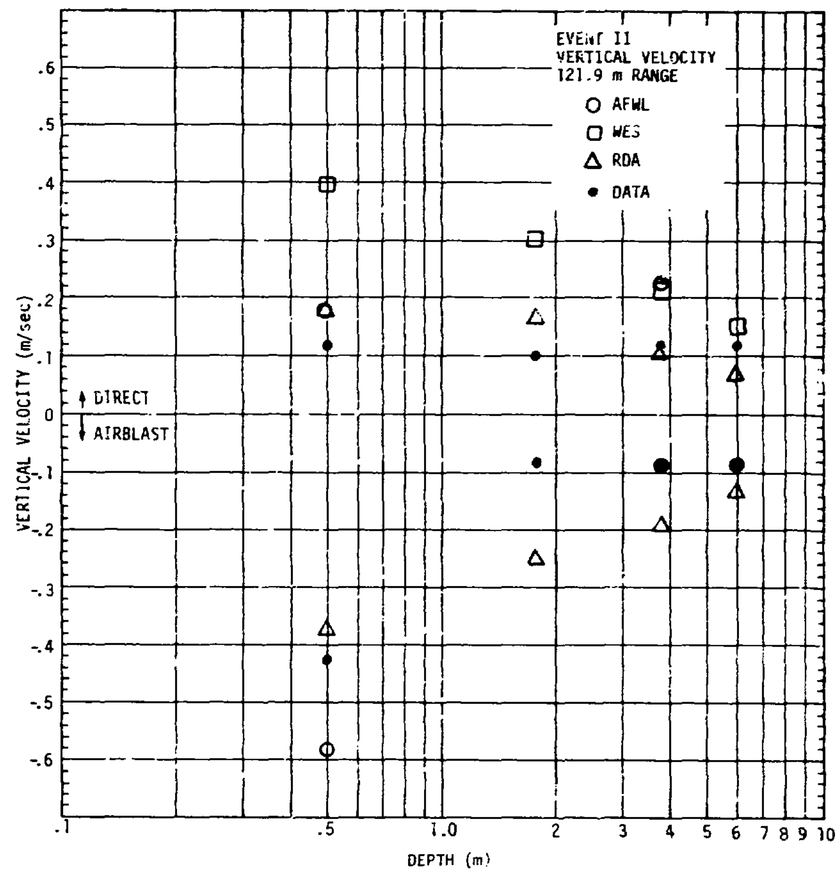


Figure 5.19. Vertical Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 2

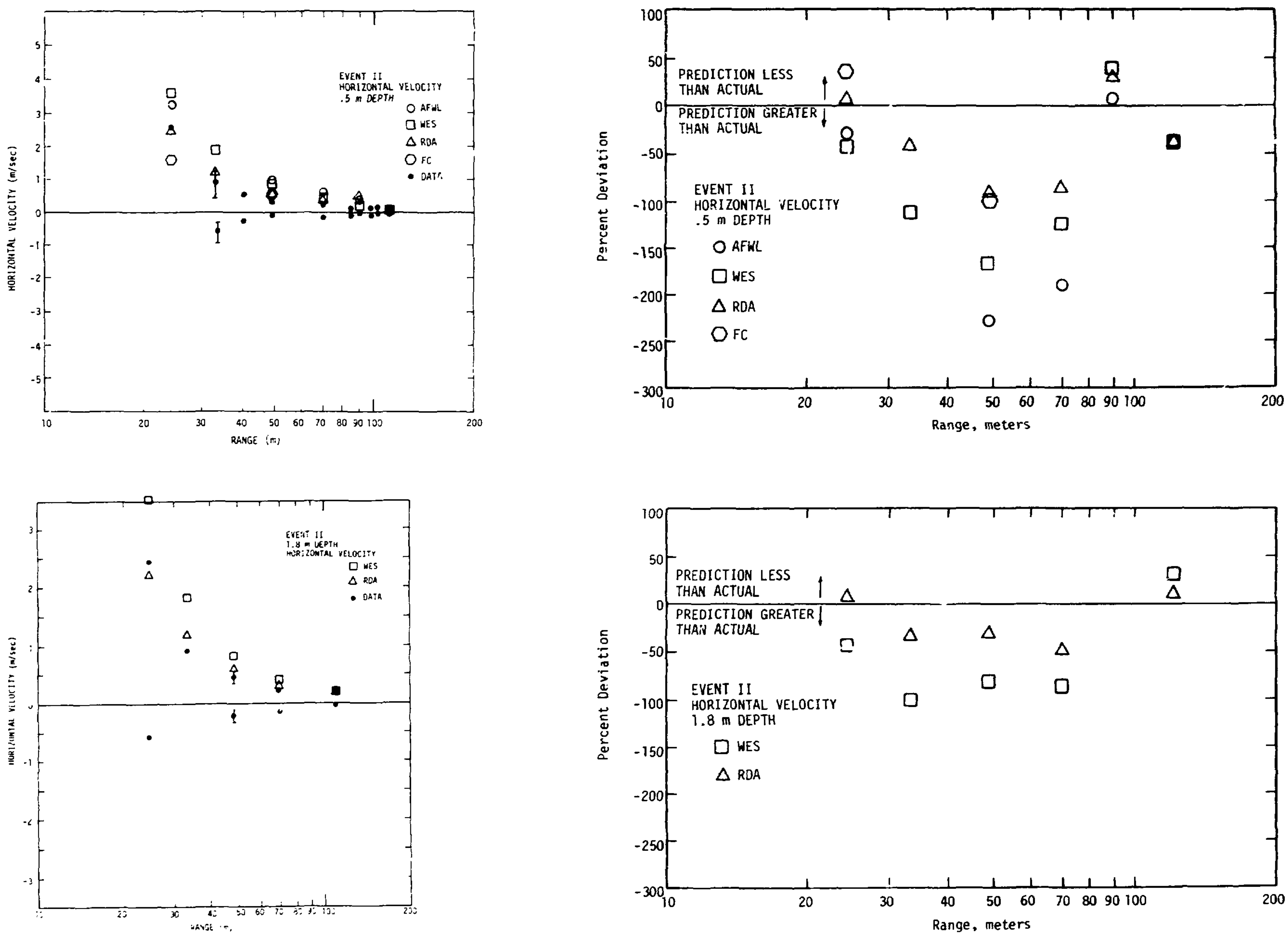


Figure 5.20. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

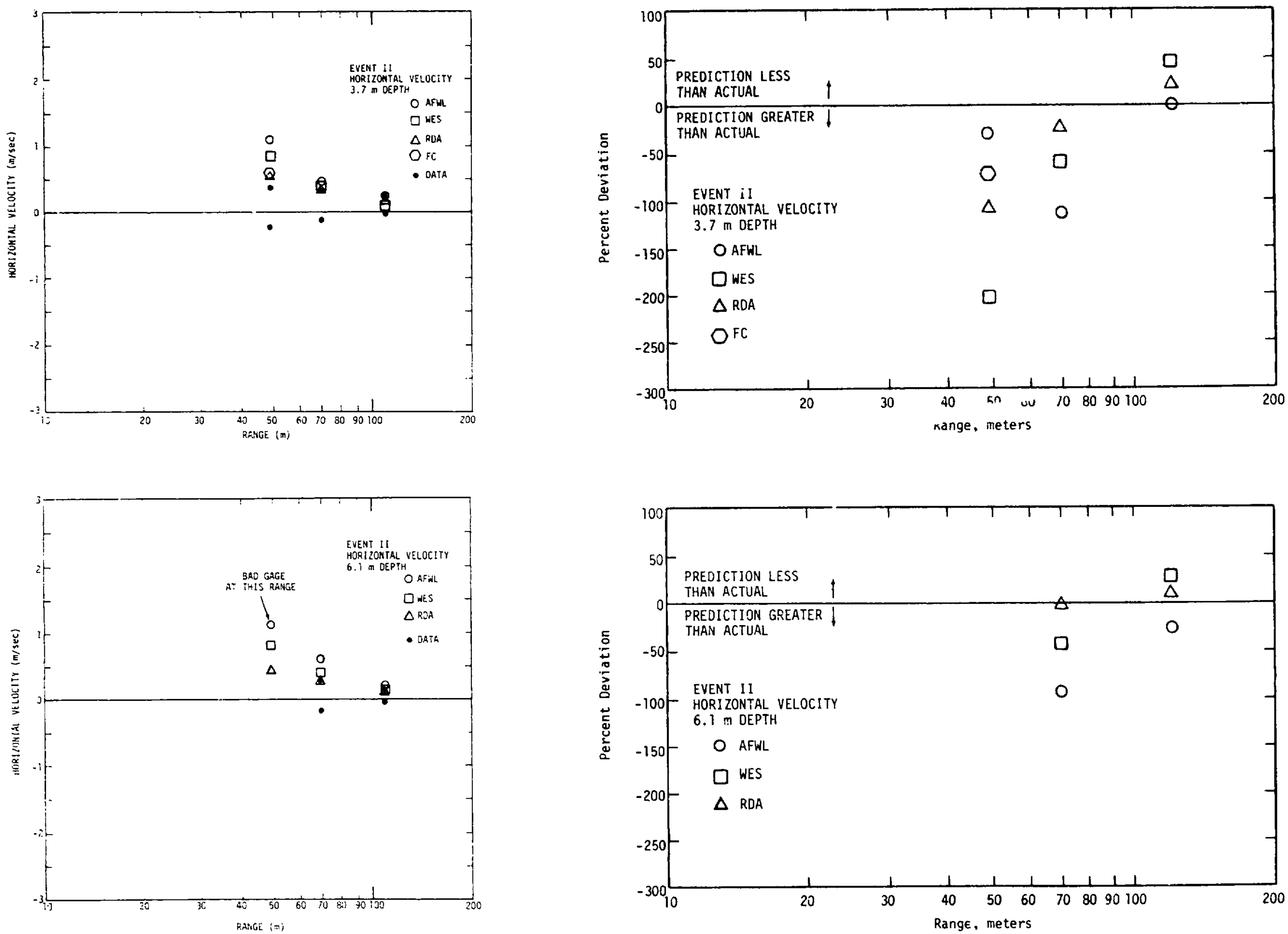


Figure 5.21. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

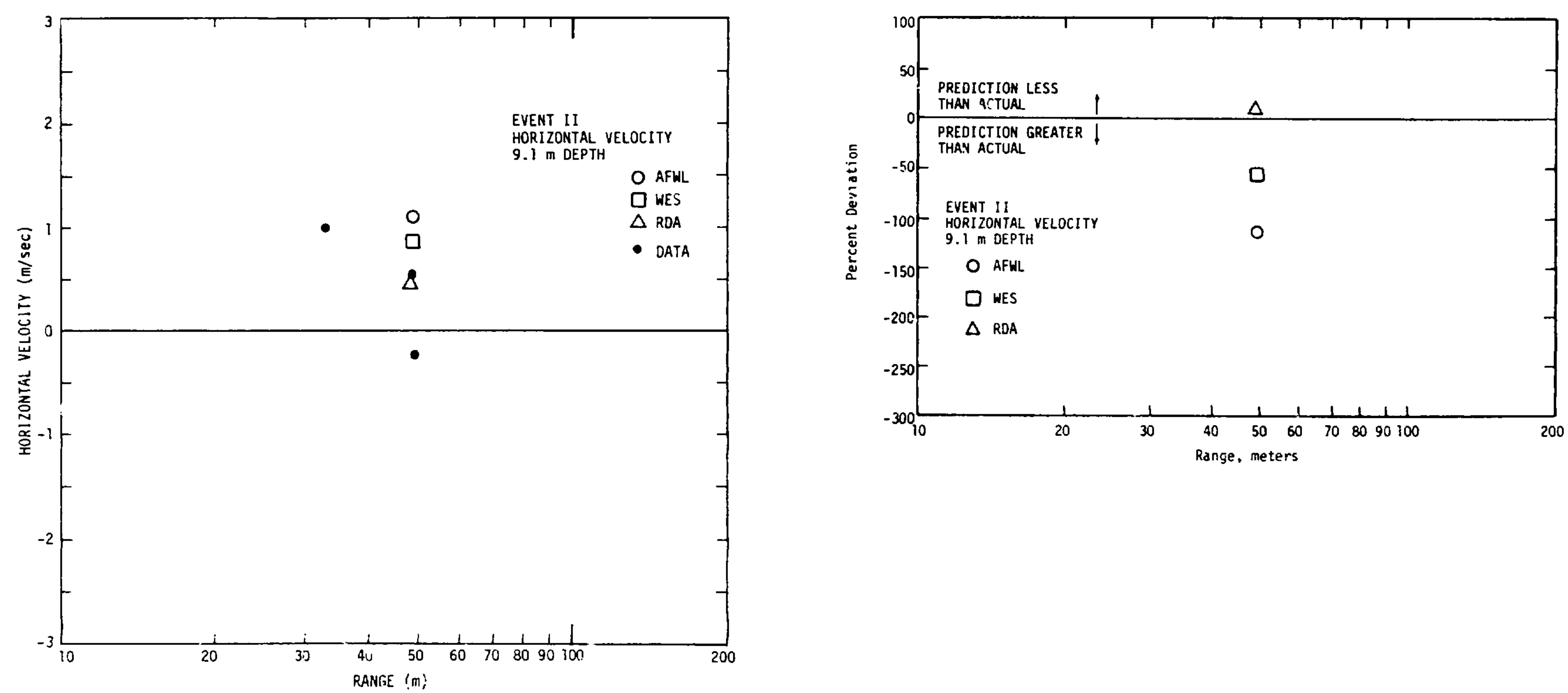


Figure 5.22. Horizontal Velocity vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

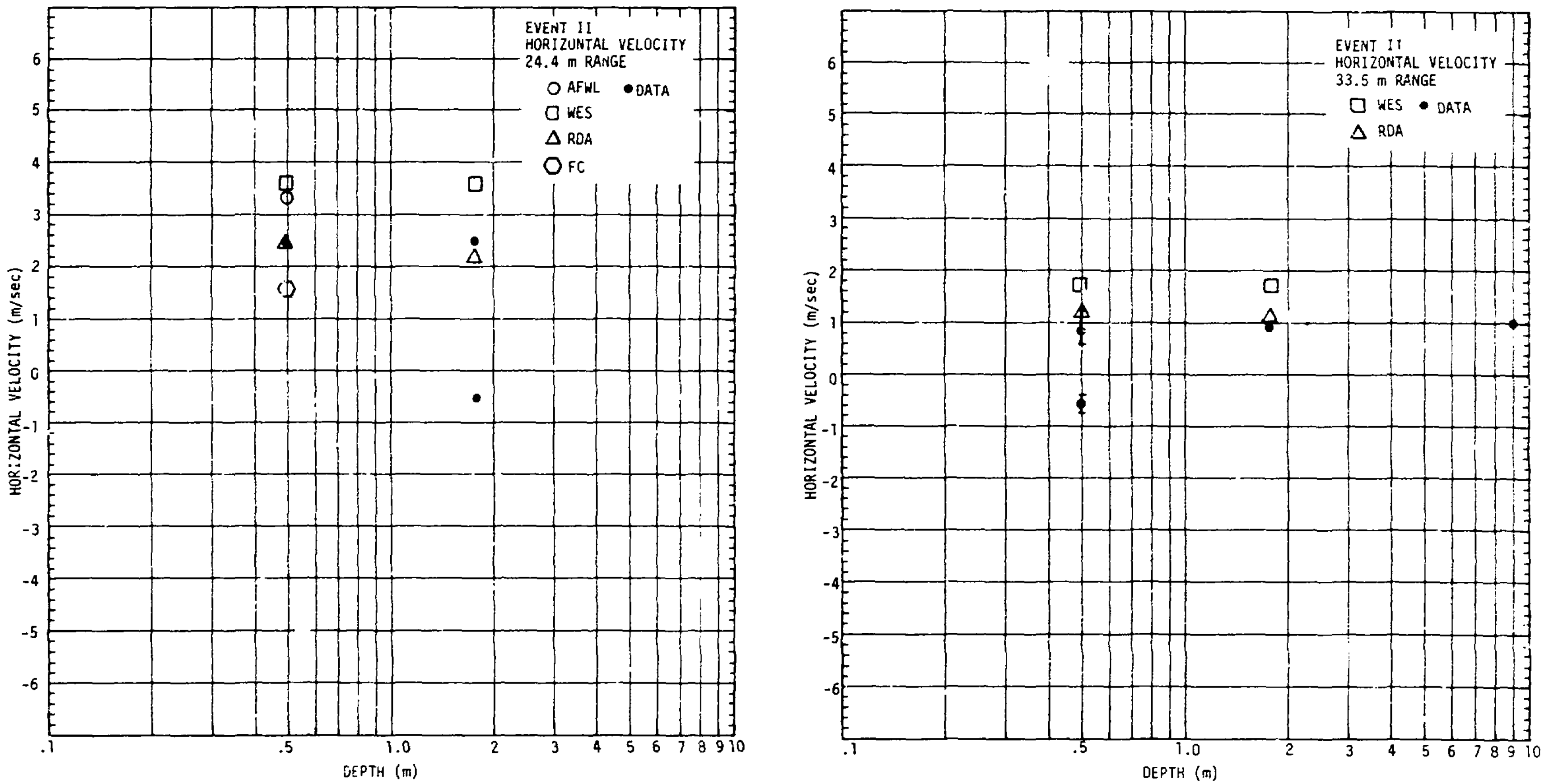


Figure 5.23. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 2

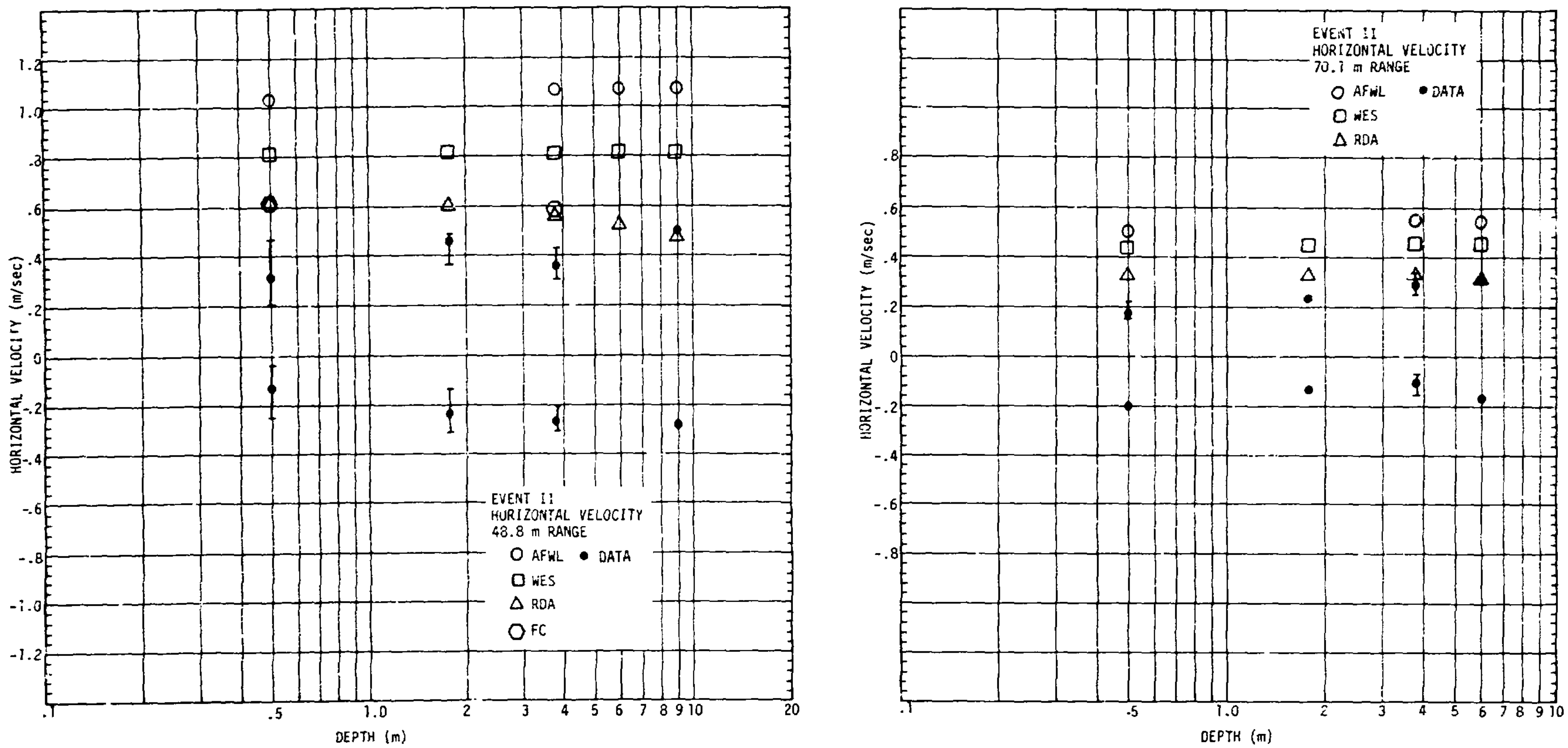


Figure 5.24. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 2

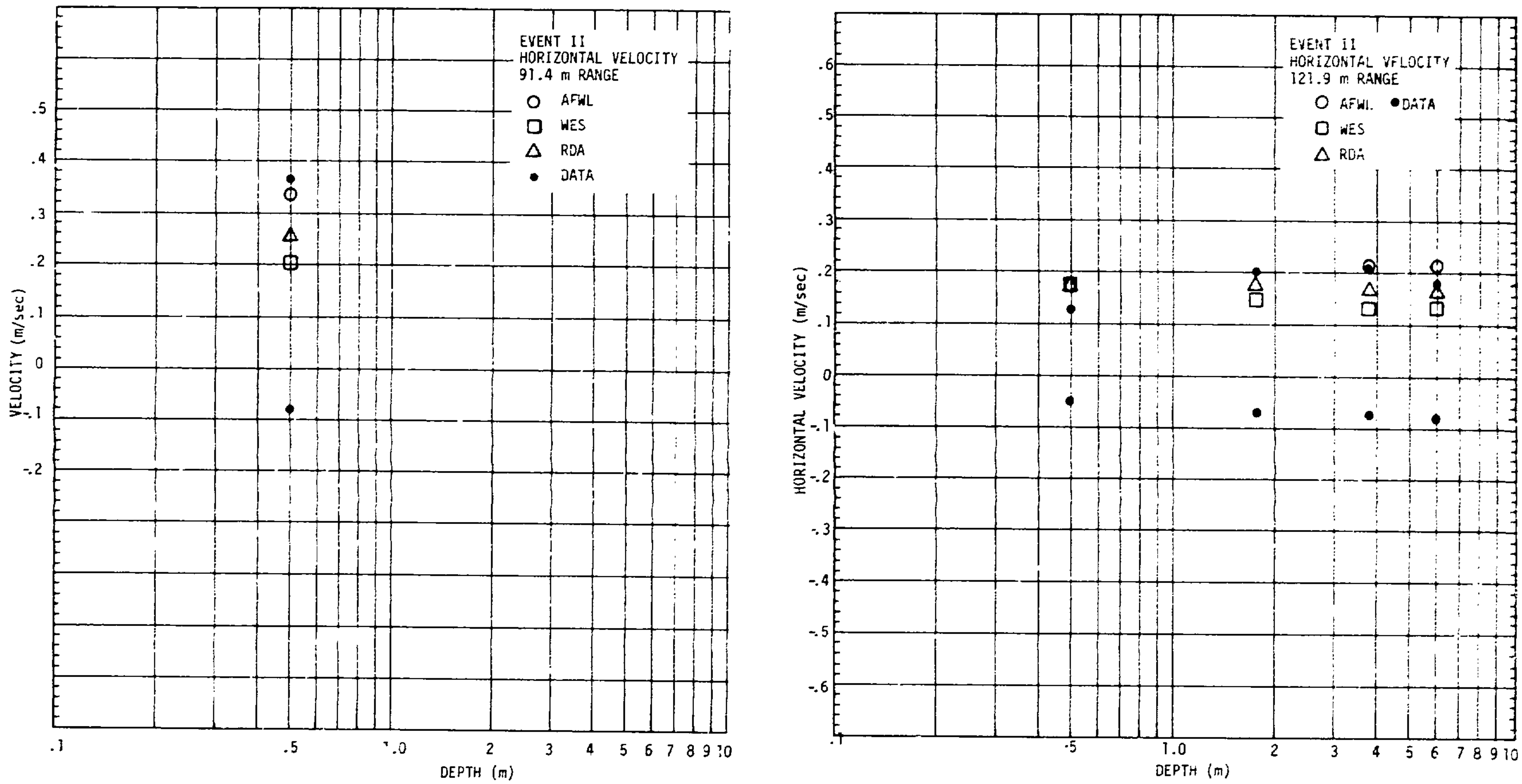


Figure 5.25. Horizontal Velocity vs. Depth with Predictions for Pre-DICE THROW II, Event 2

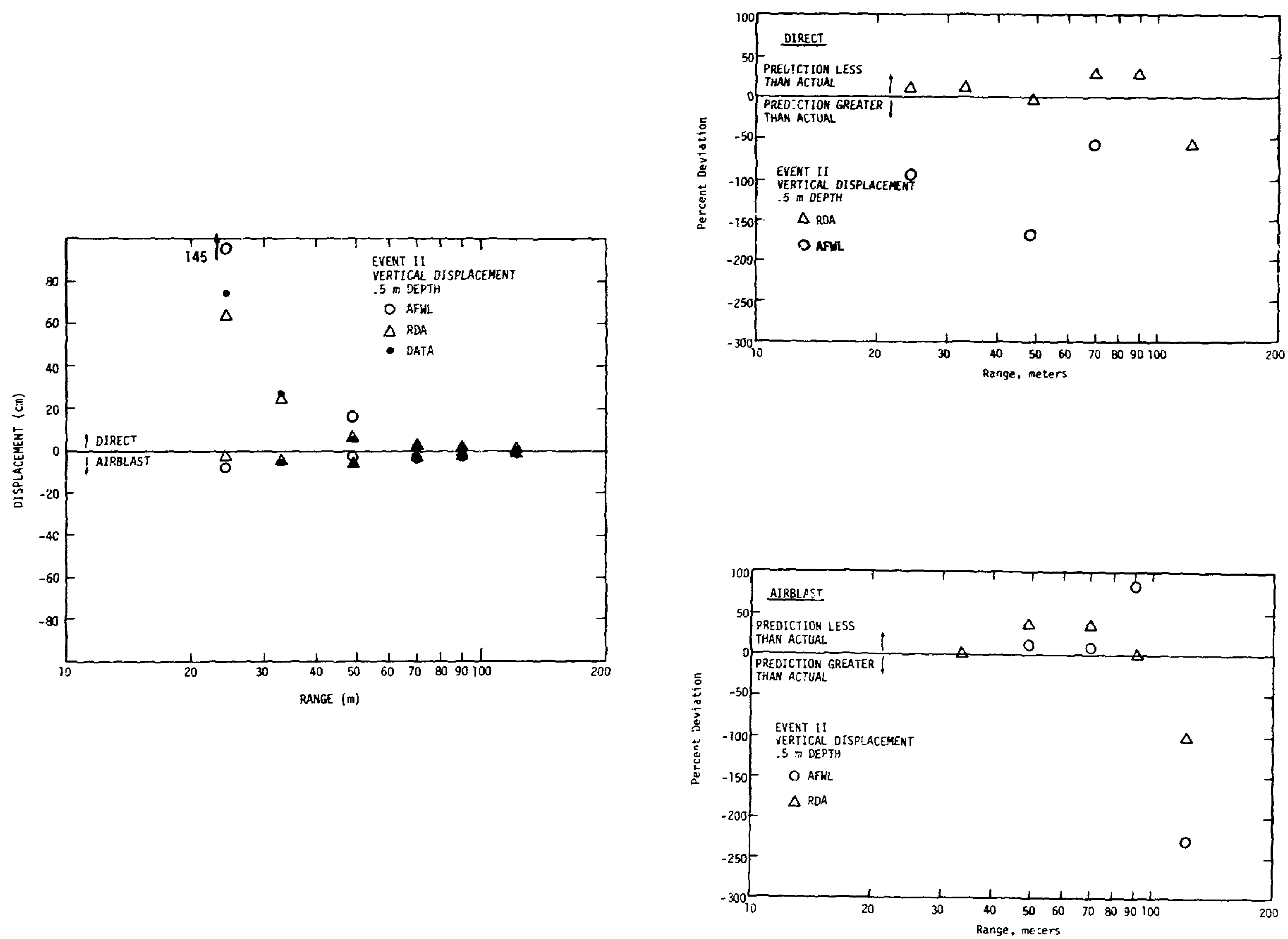
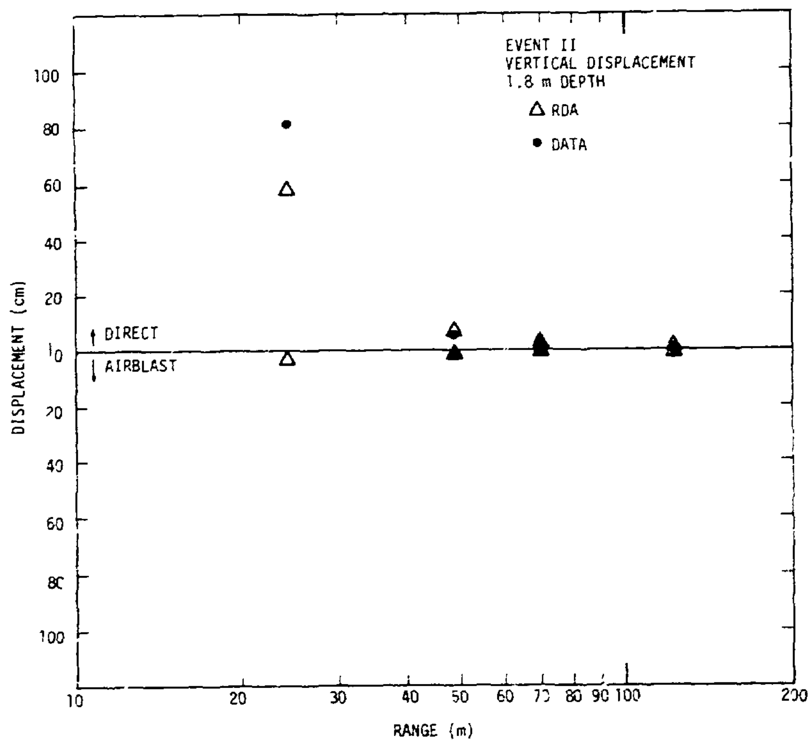
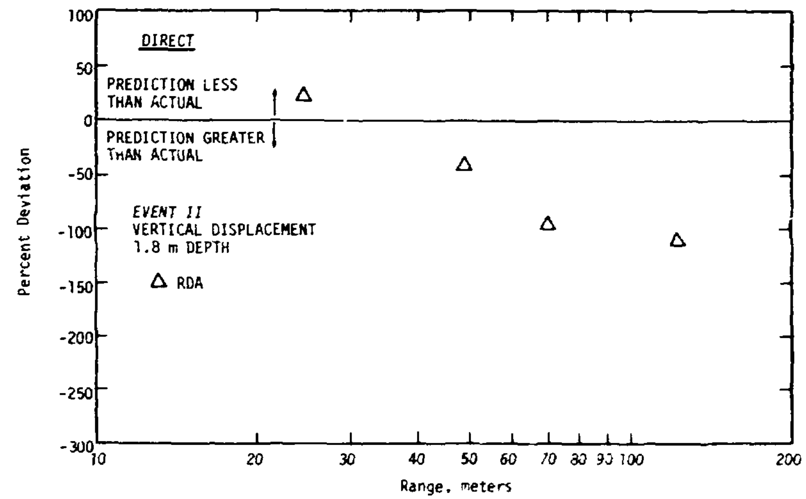


Figure 5.26. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2





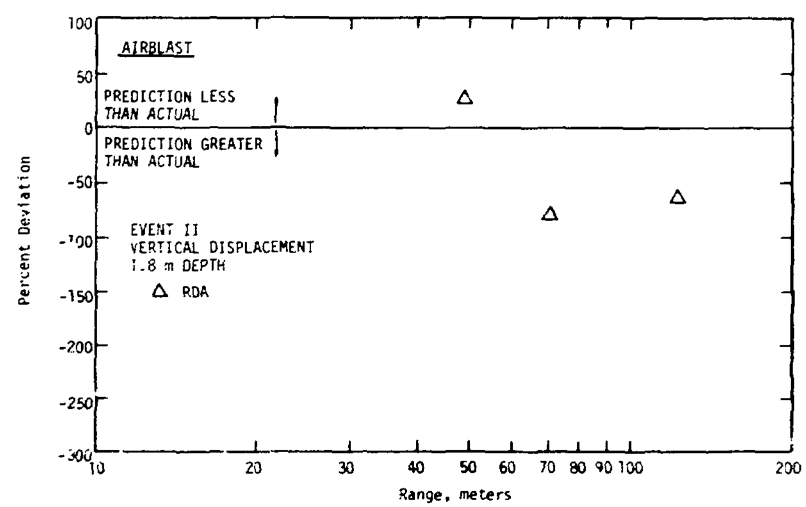


Figure 5.27. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

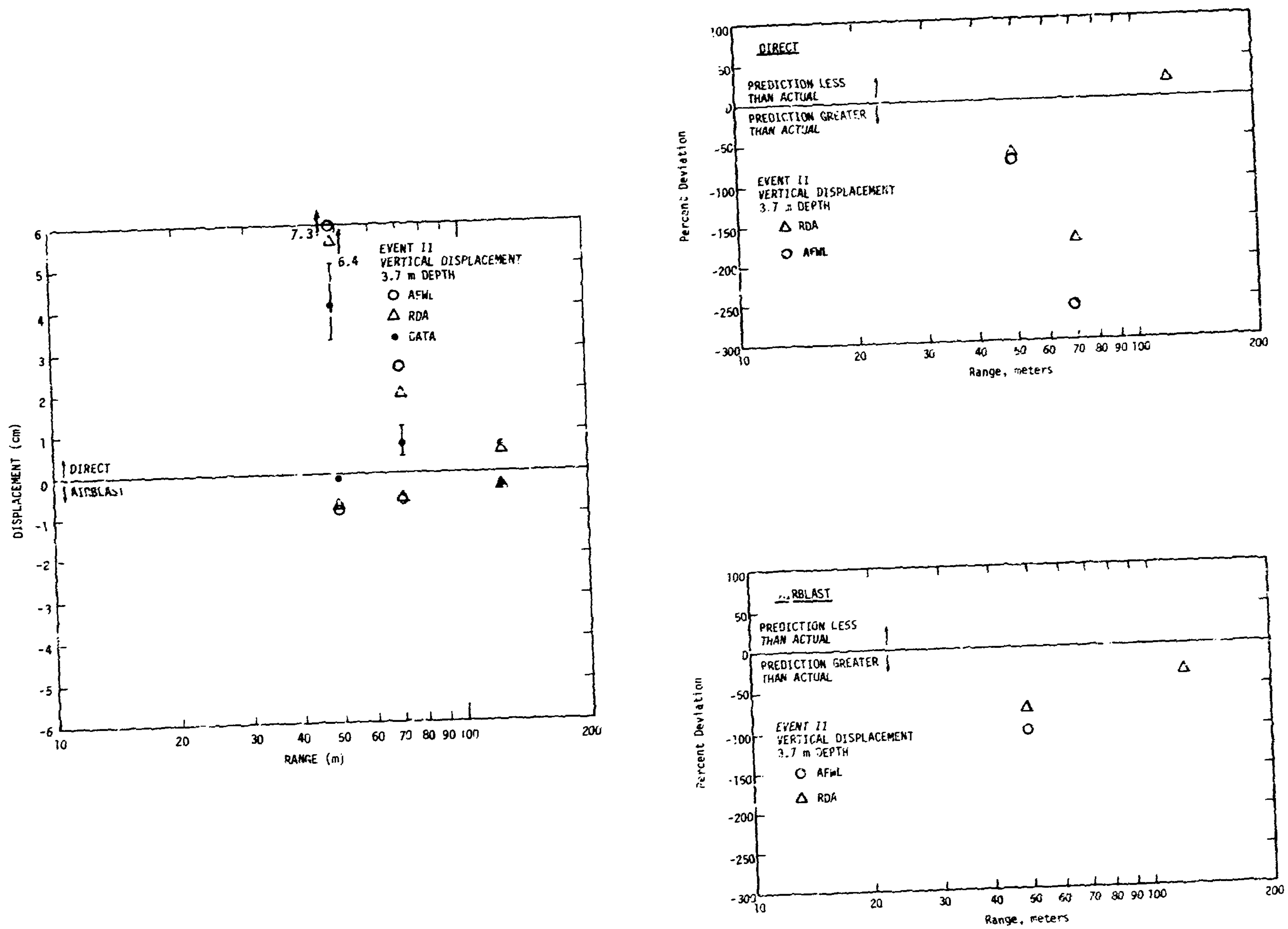


Figure 5.28. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

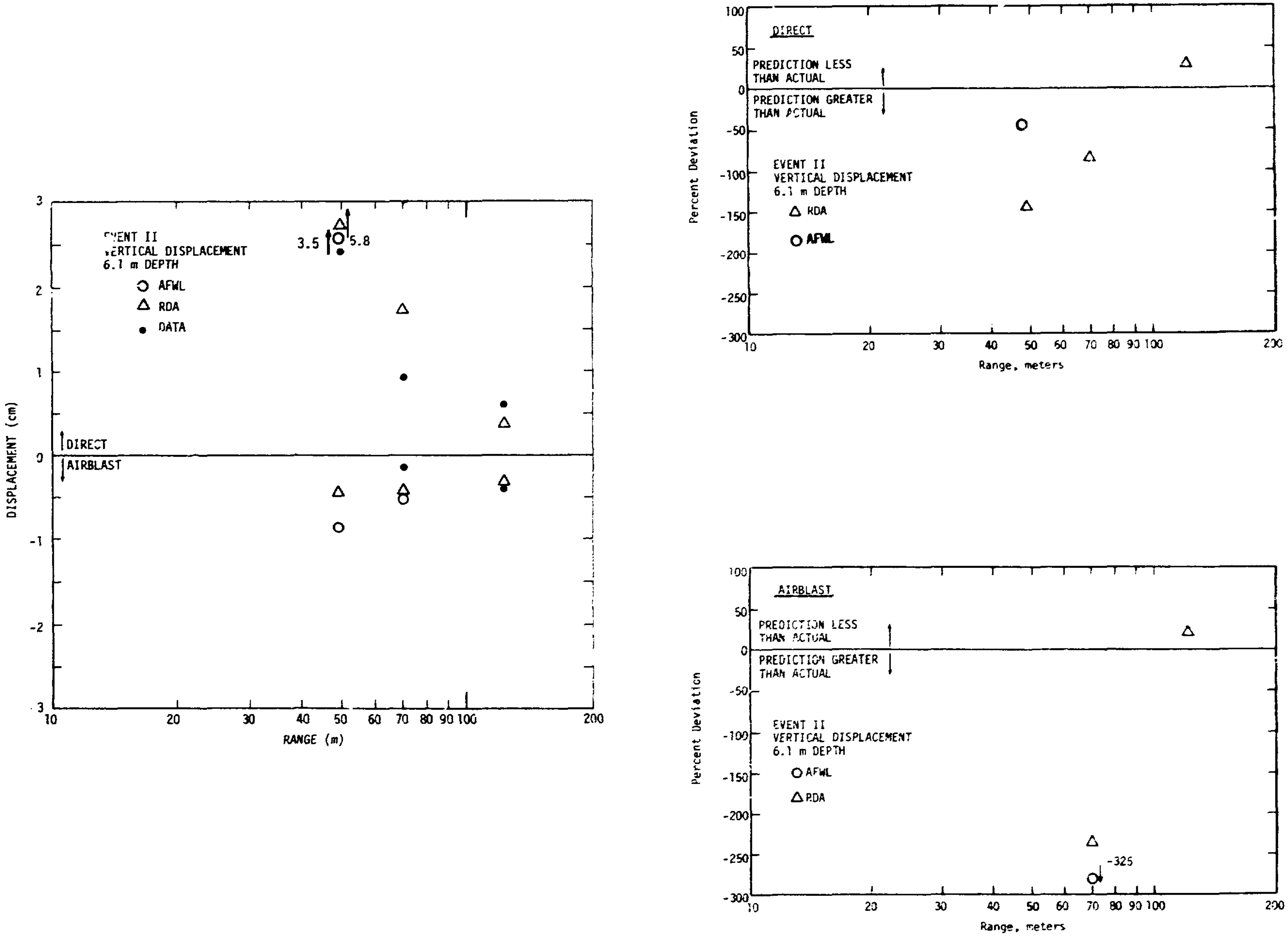


Figure 5.29. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

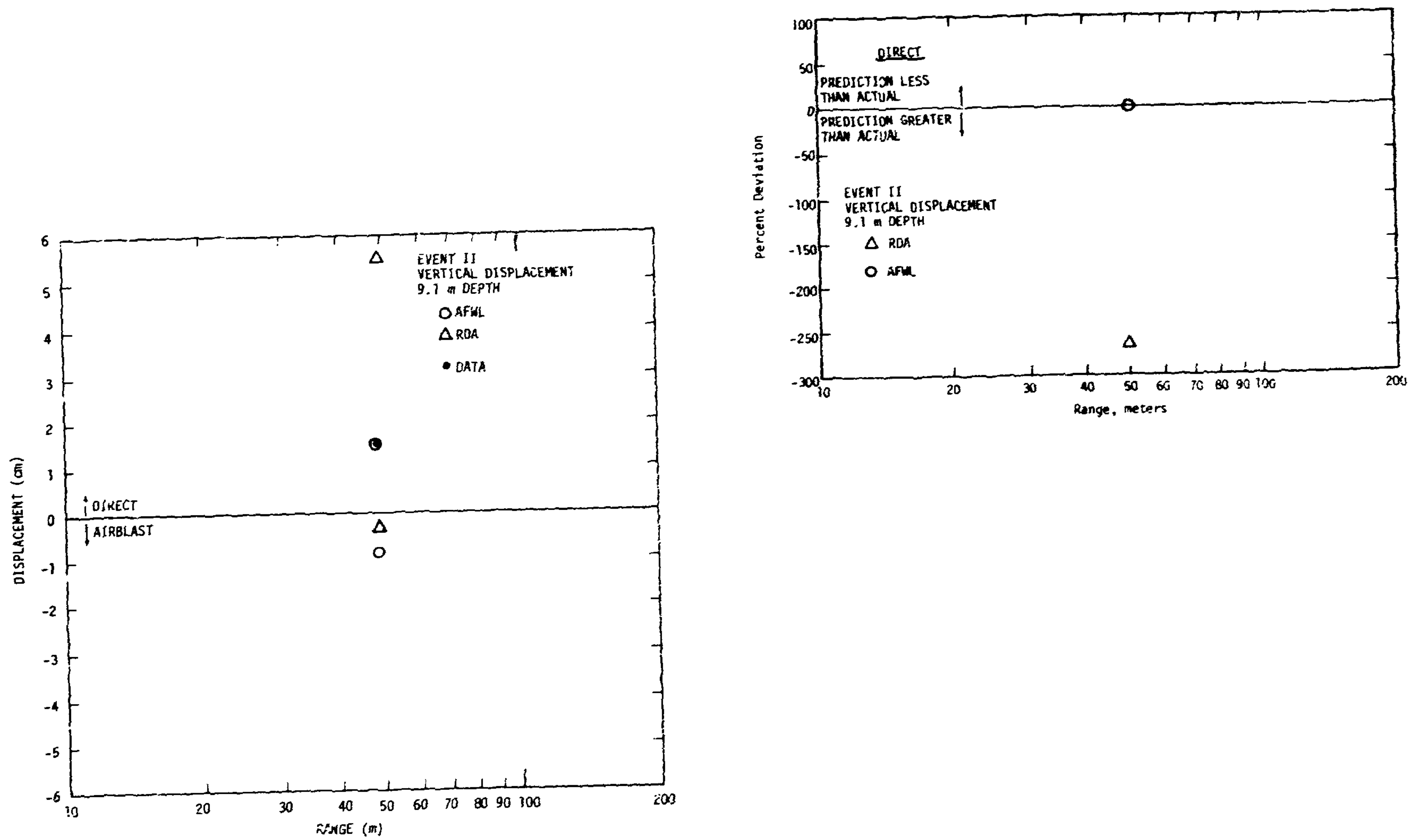
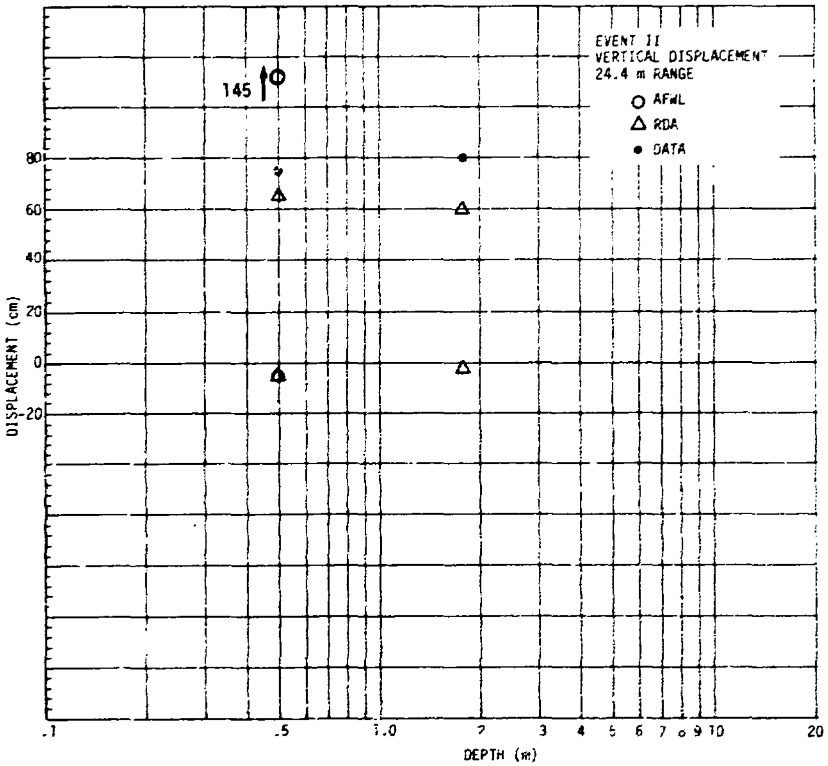


Figure 5.30. Vertical Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2



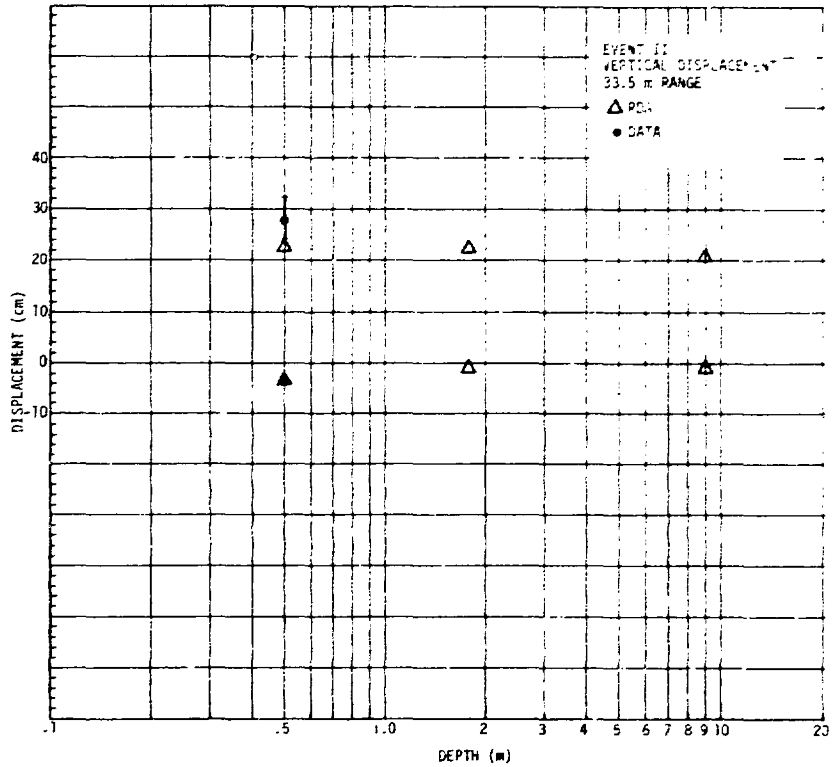


Figure 5.31. Vertical Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

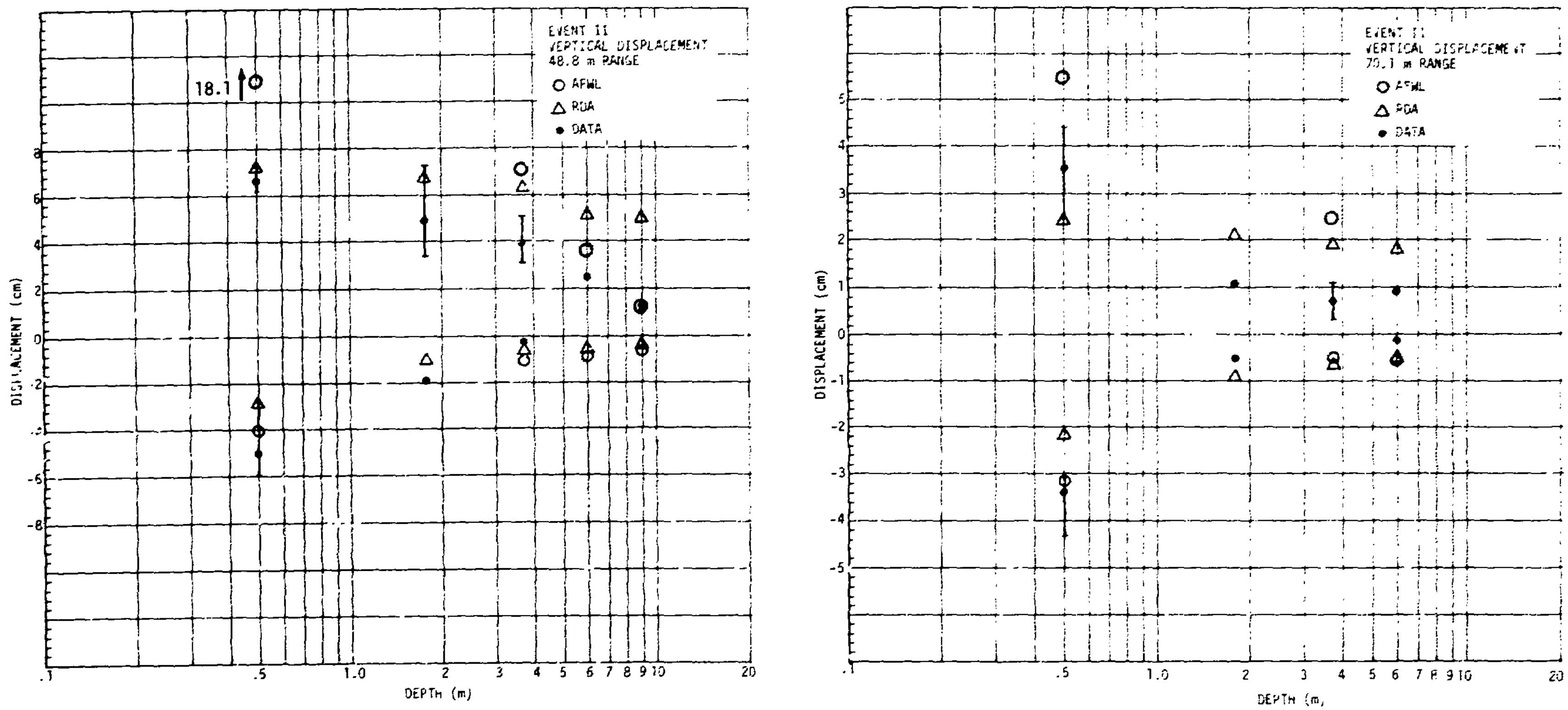


Figure 5.32. Vertical Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

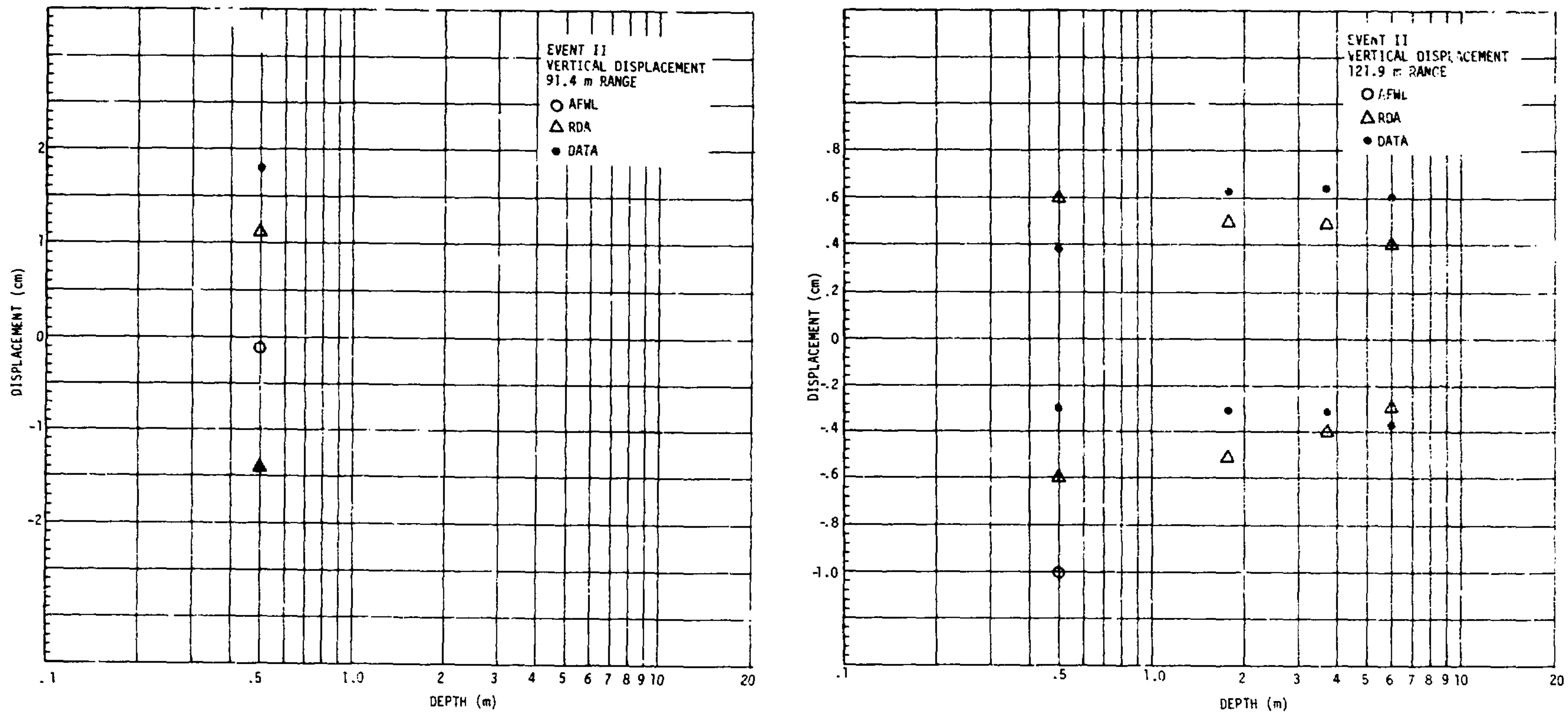


Figure 5.33. Vertical Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

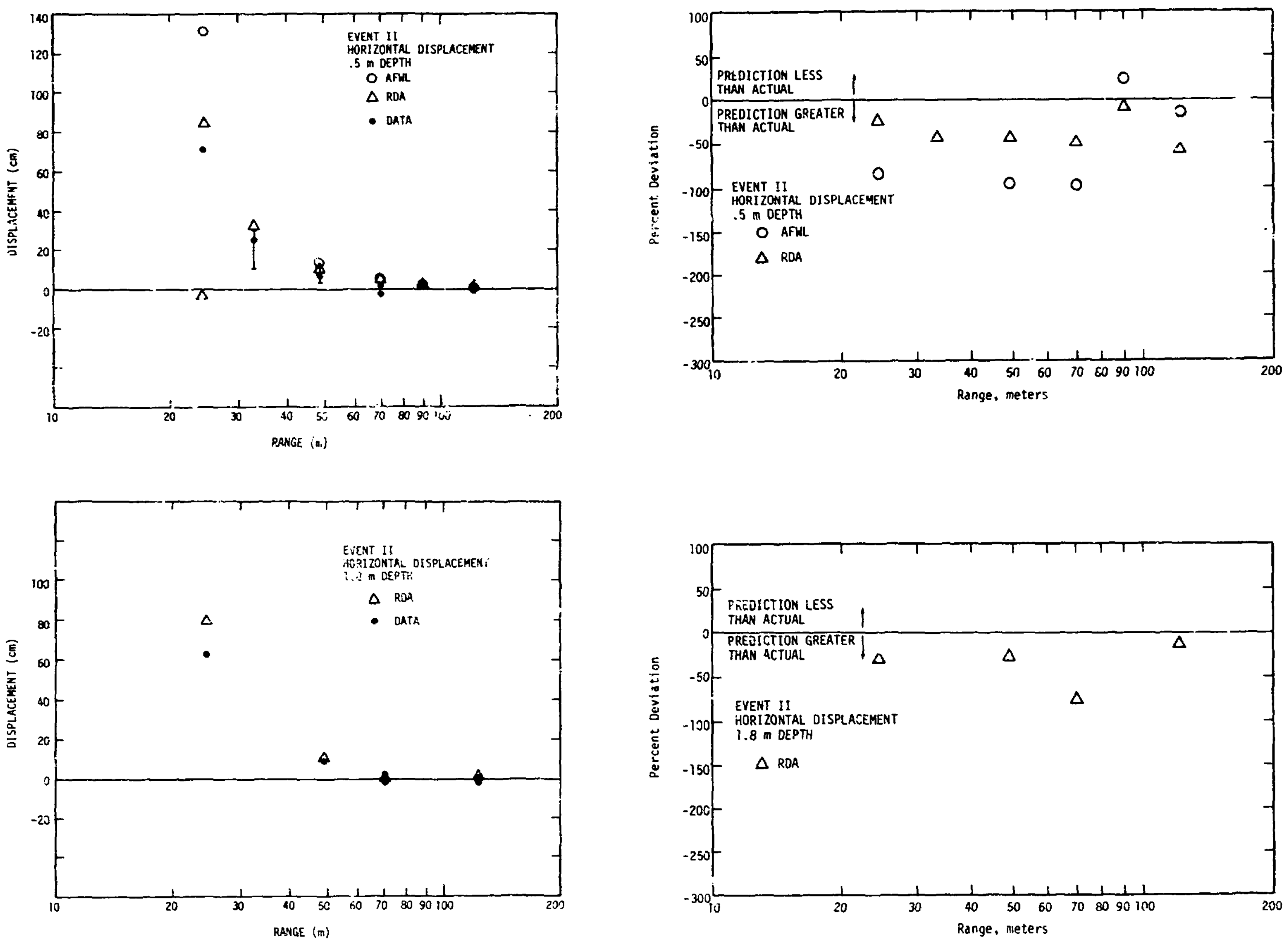


Figure 5.34. Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

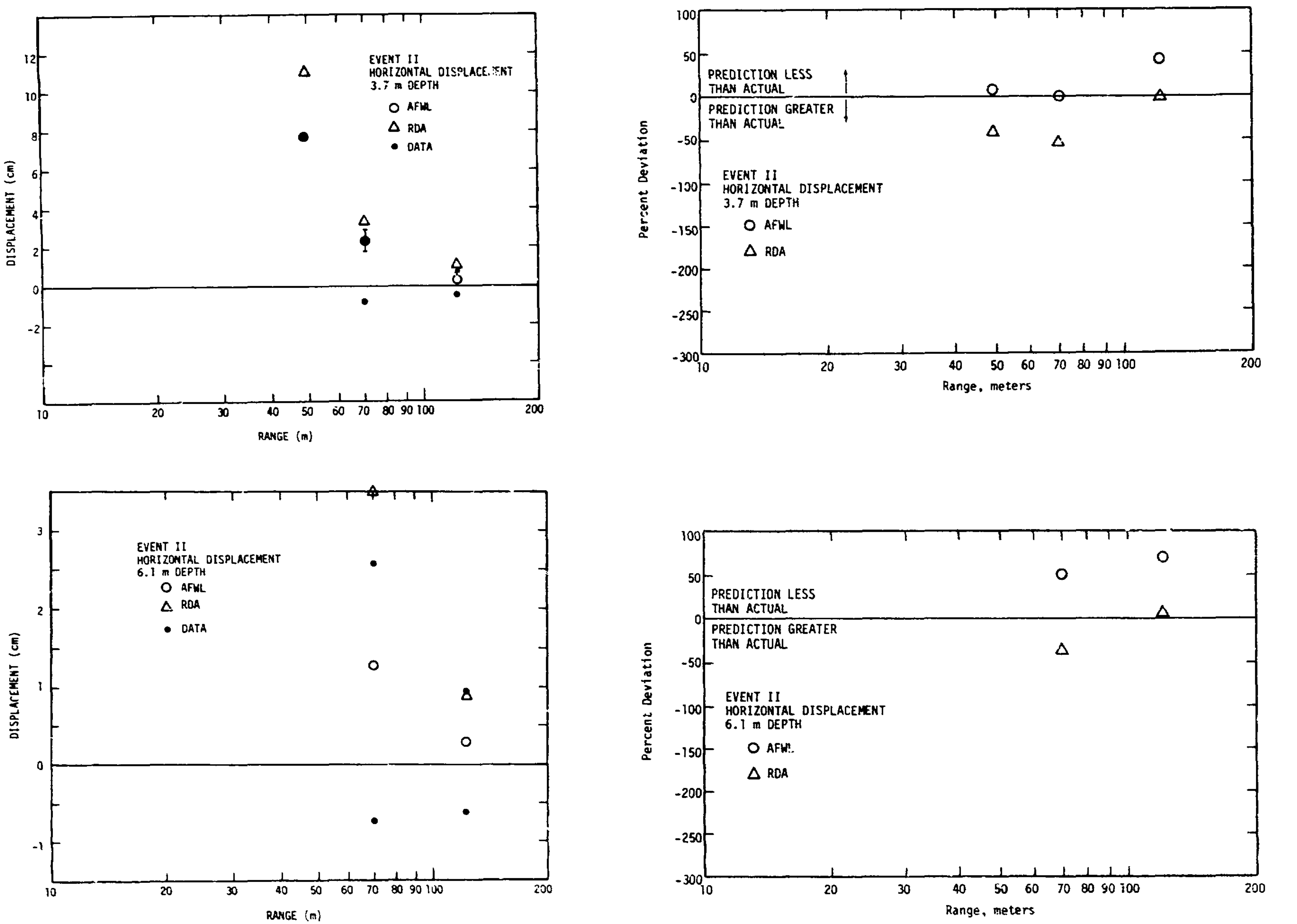


Figure 5.35. Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2

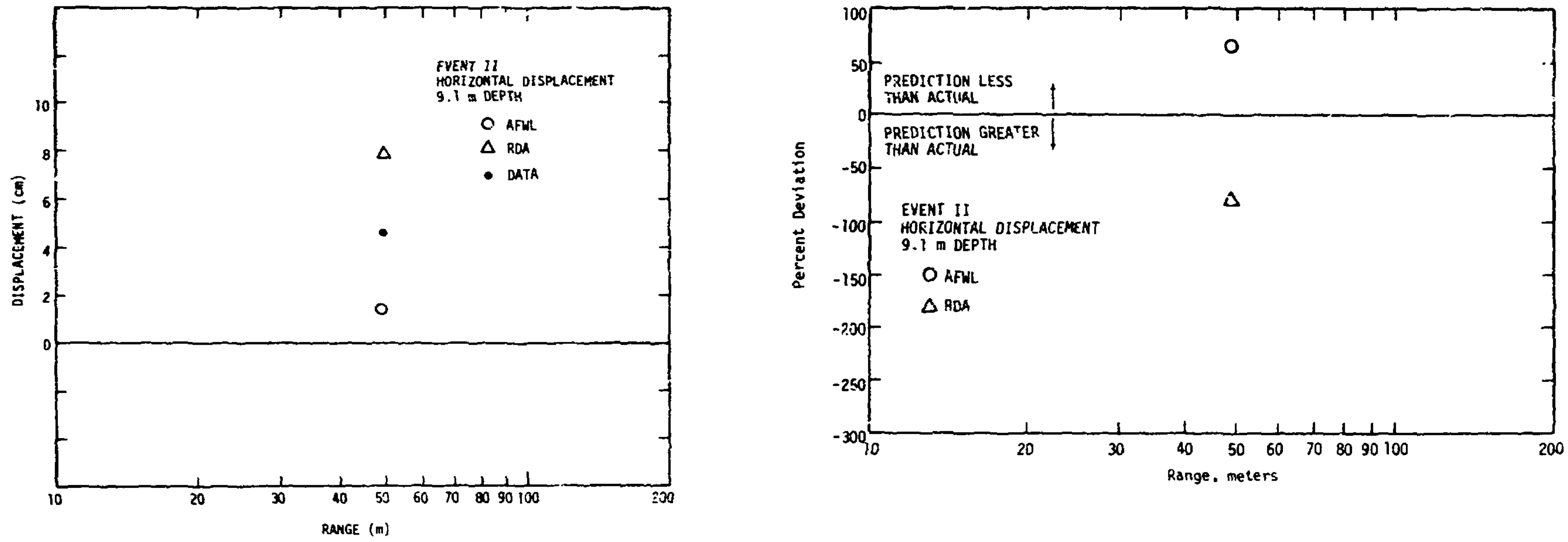


Figure 5.36. *Horizontal Displacement vs. Range with Predictions and Deviations for Pre-DICE THROW II, Event 2*

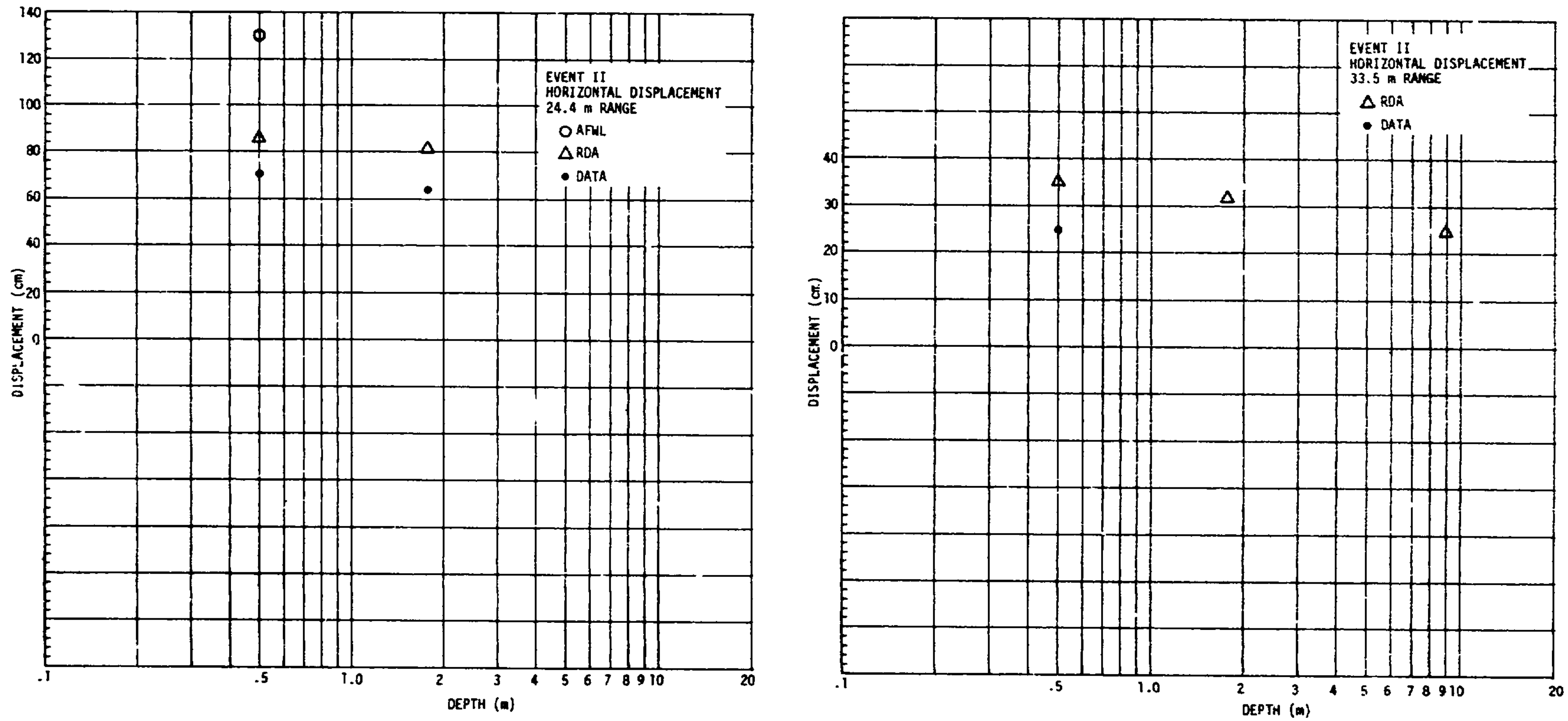


Figure 5.37. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

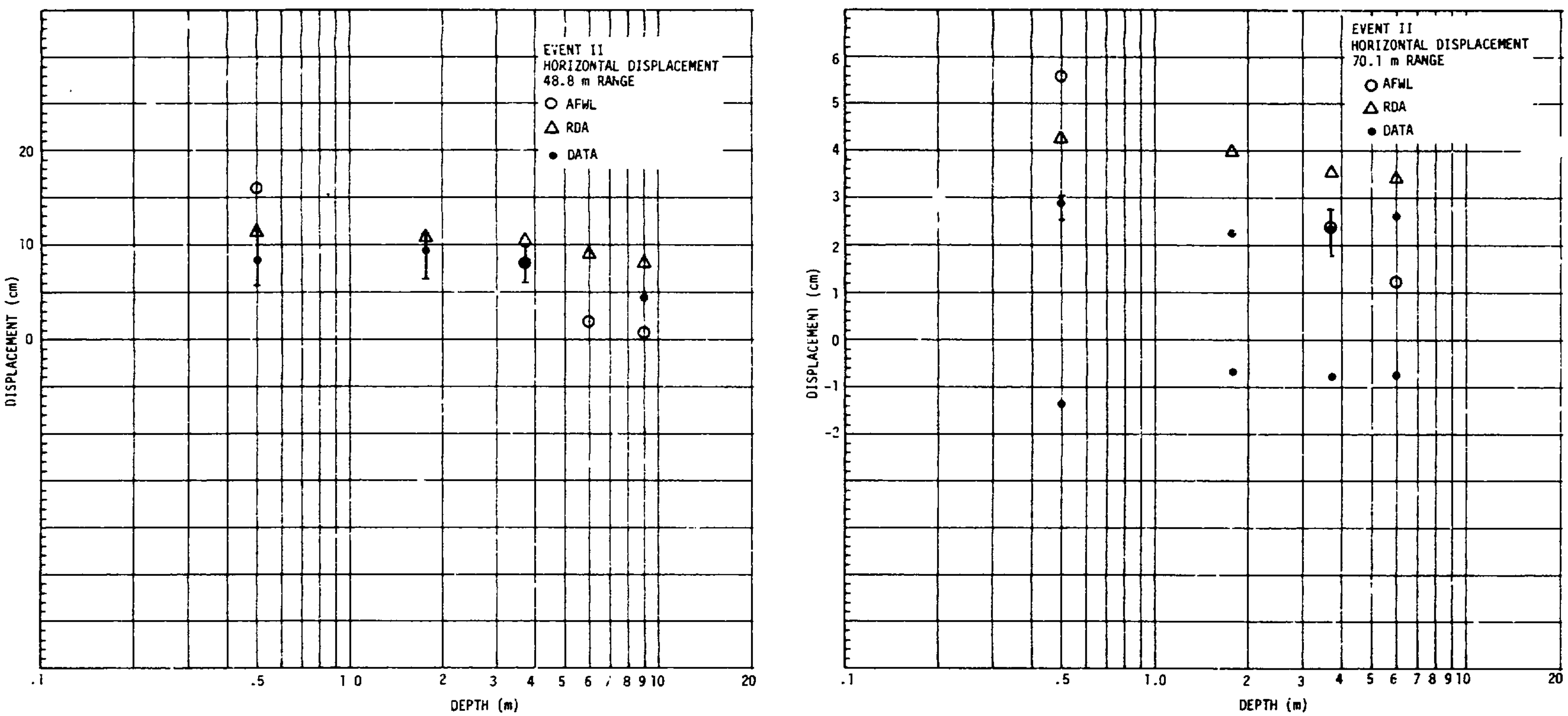


Figure 5.38. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

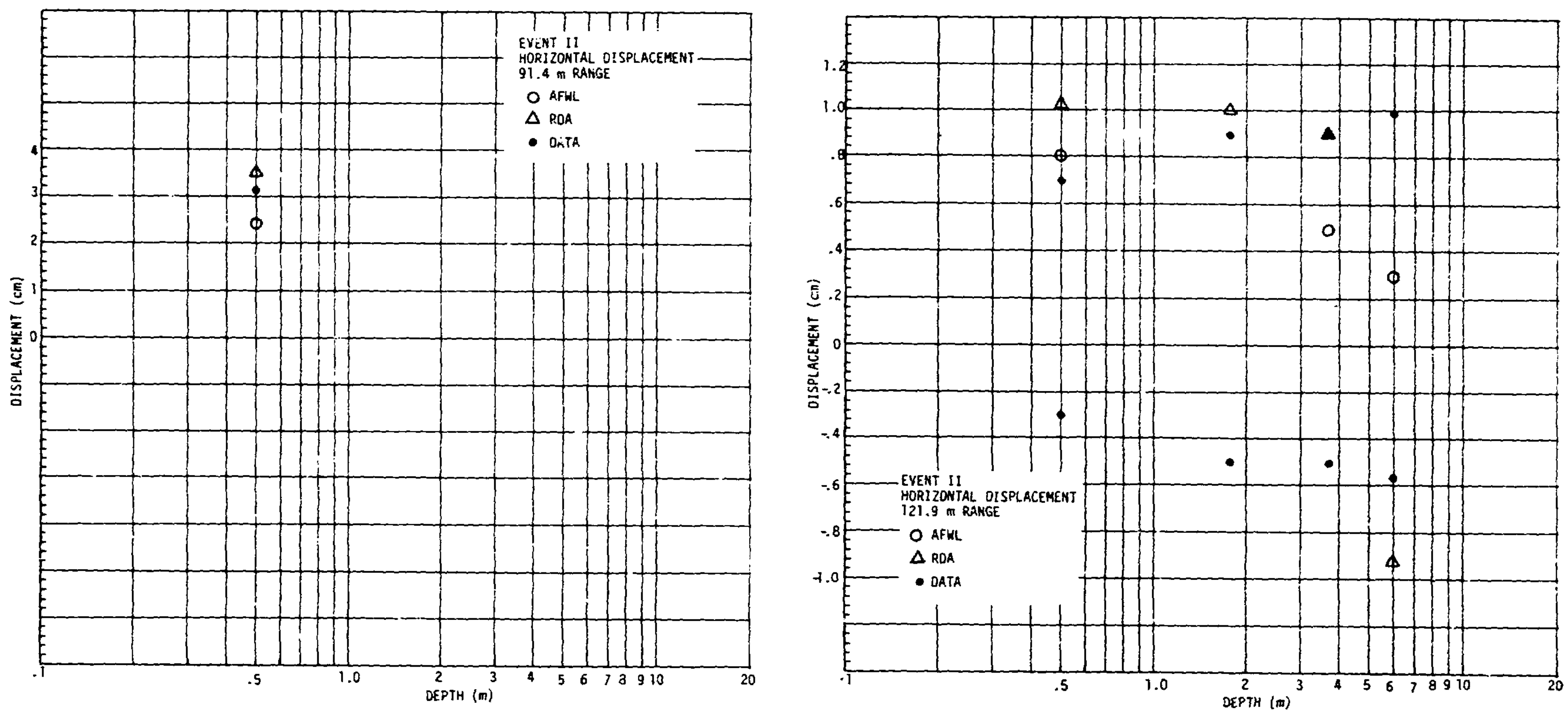


Figure 5.39. Horizontal Displacement vs. Depth with Predictions for Pre-DICE THROW II, Event 2

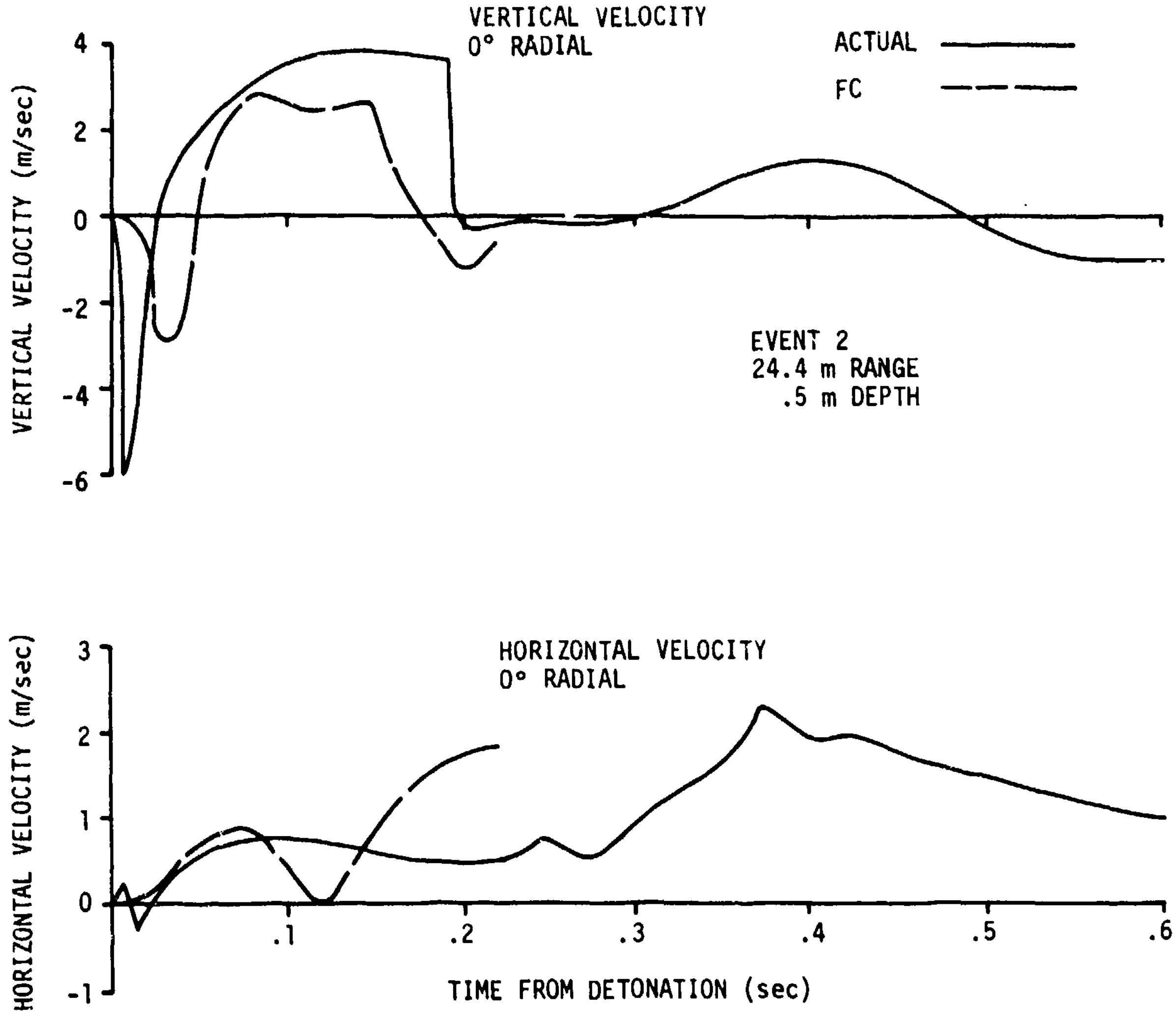


Figure 5.40. Velocity Waveforms and Predictions fc ^ Pre-DICE THROW II, Event 2

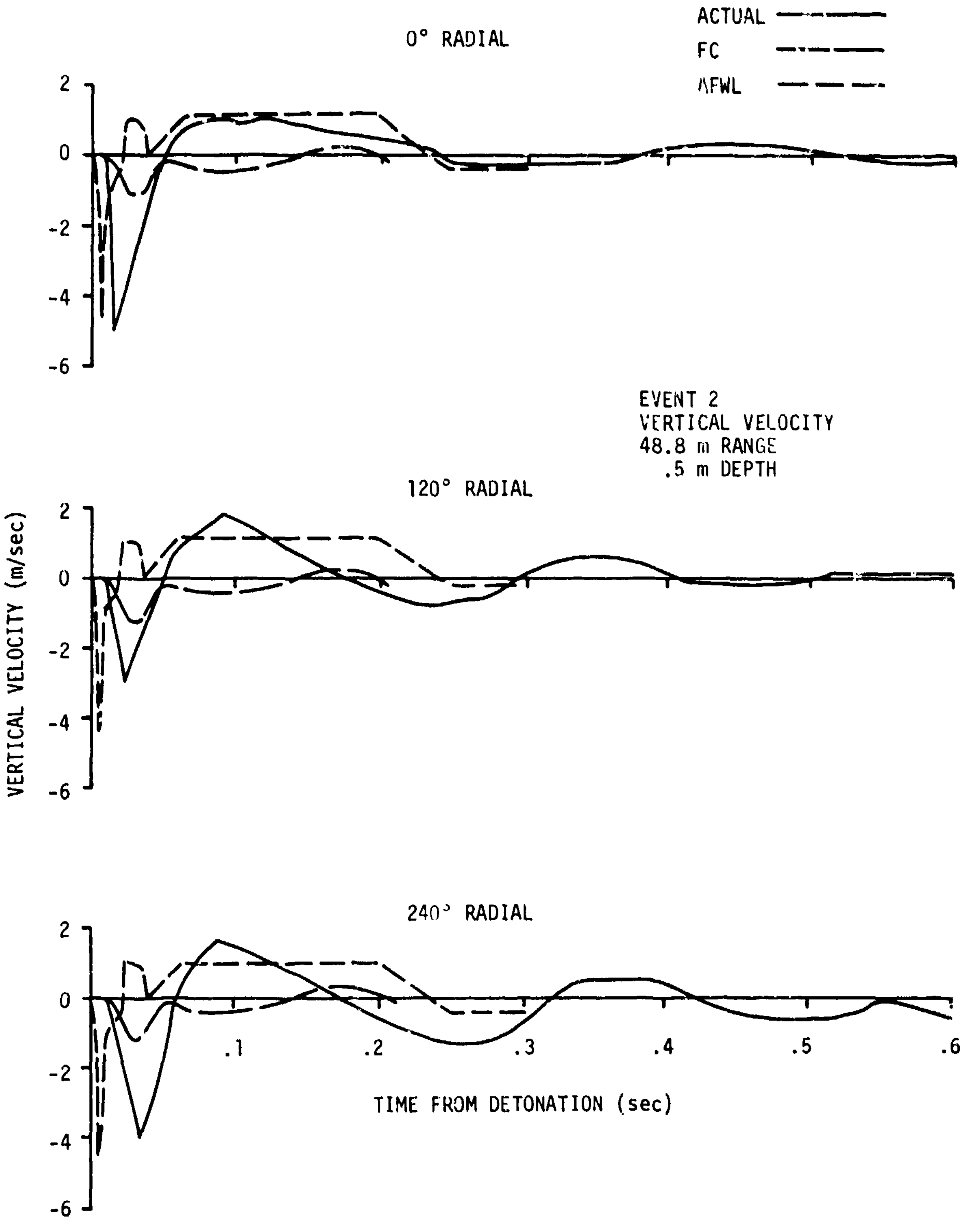


Figure 5.41. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

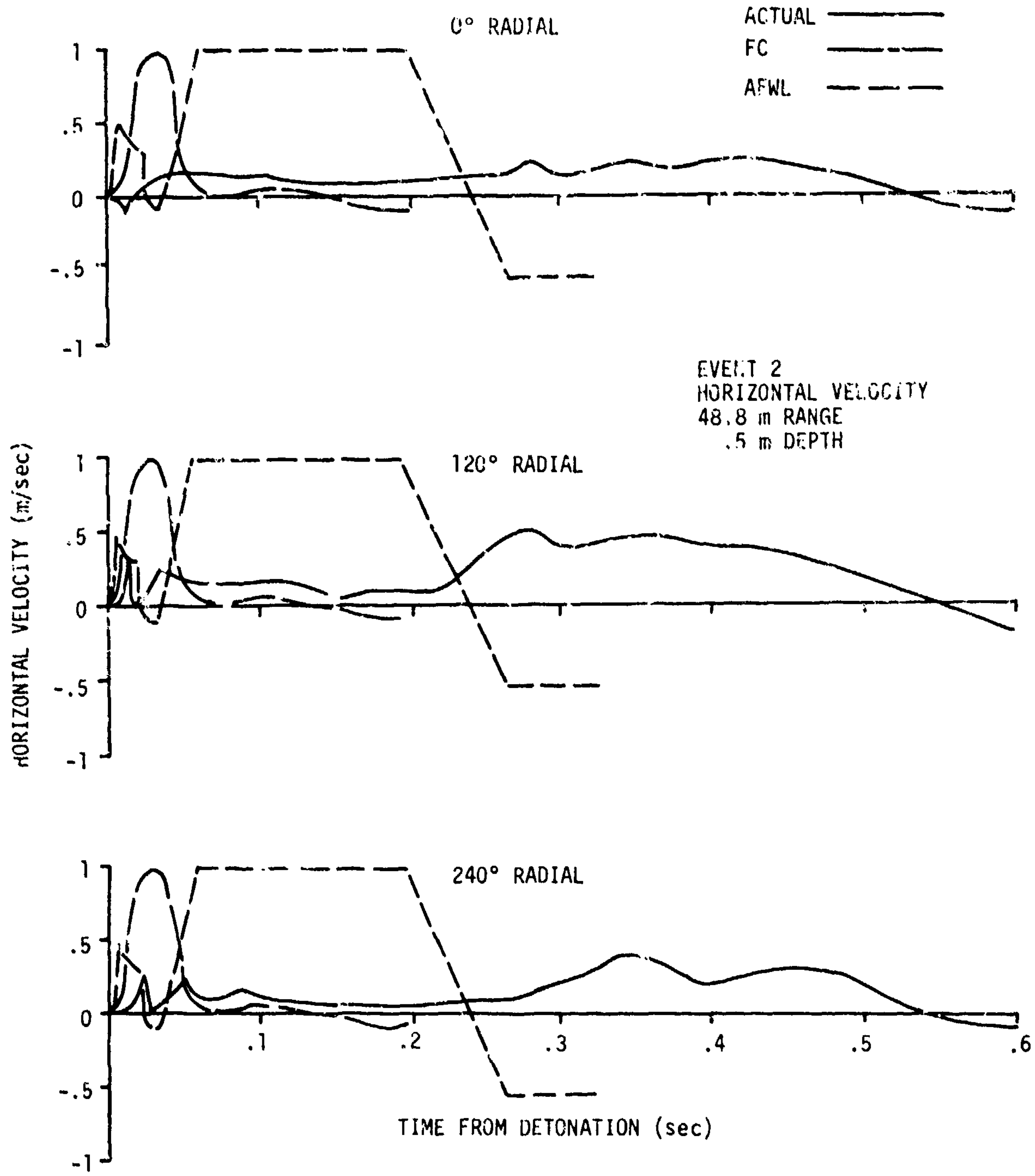


Figure 5.42. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

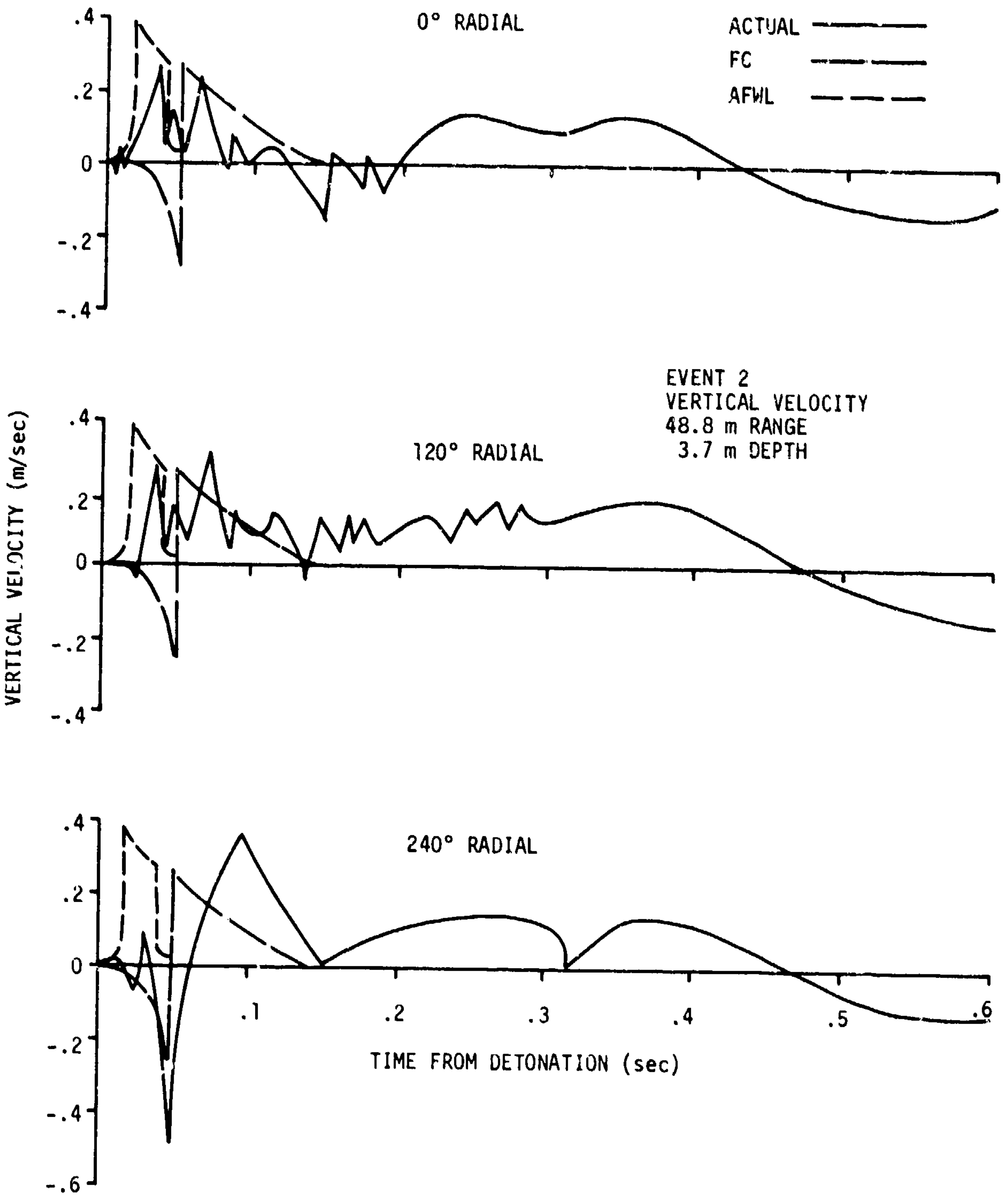


Figure 5.43. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

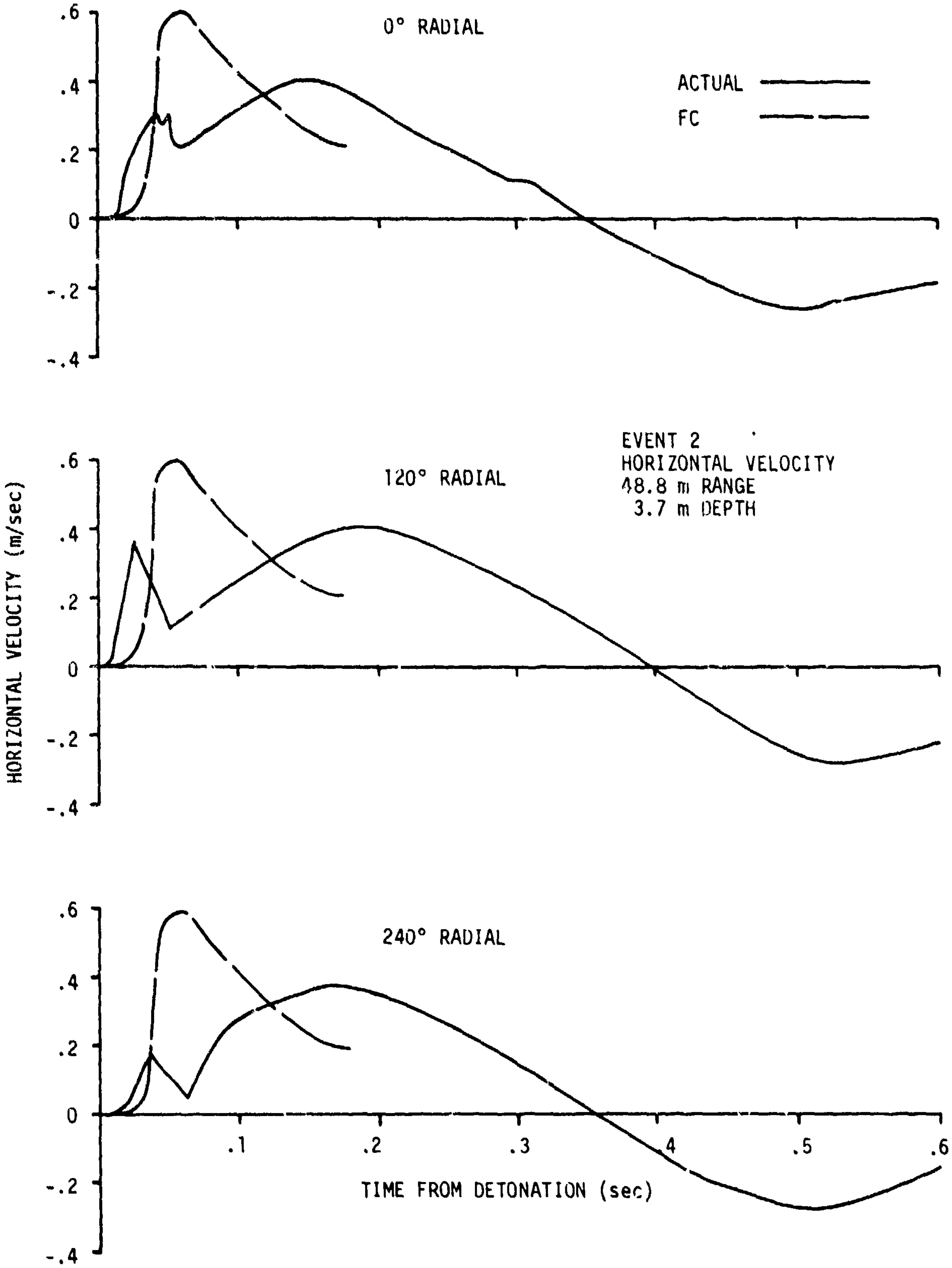


Figure 5.44. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

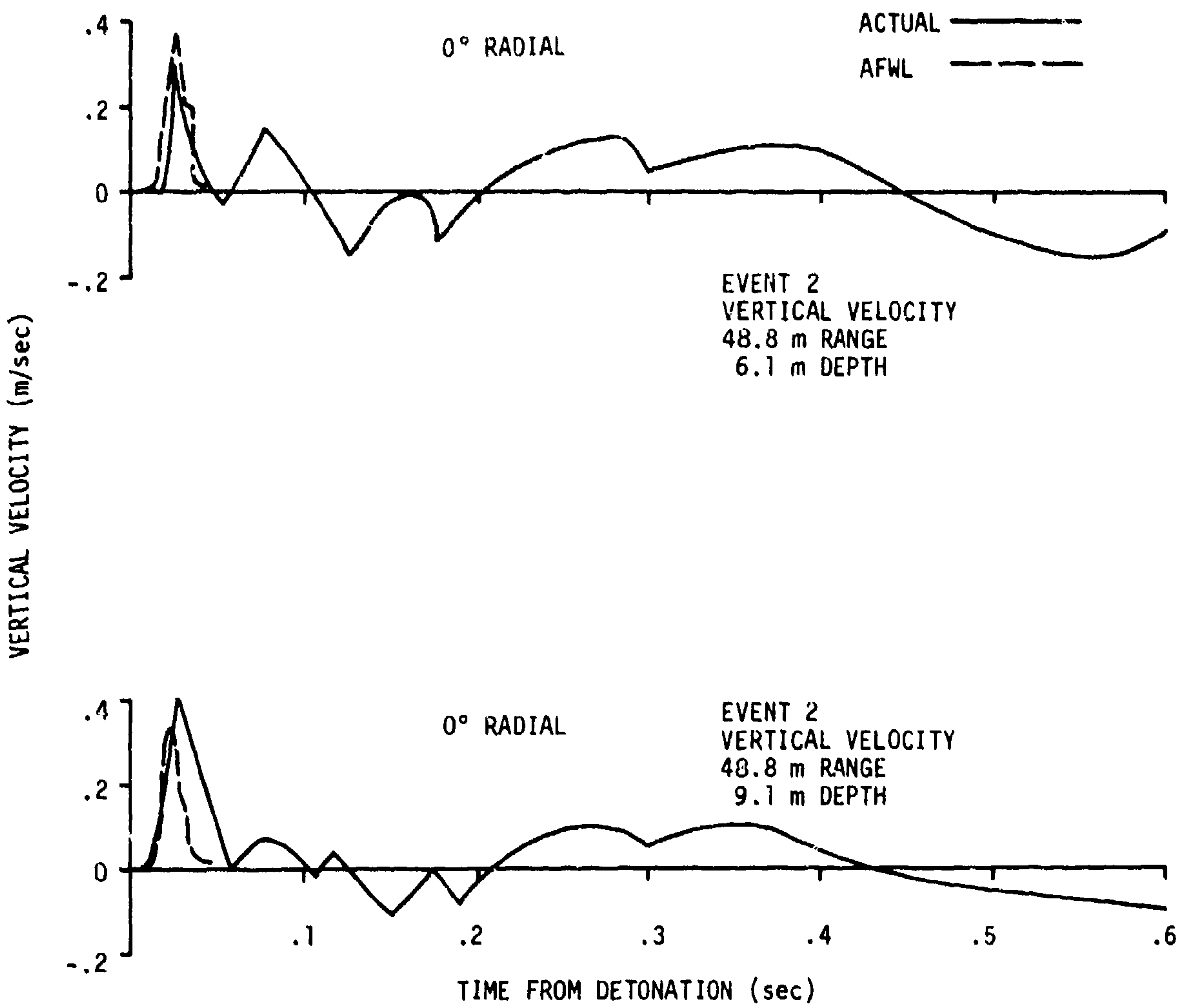


Figure 5.45. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

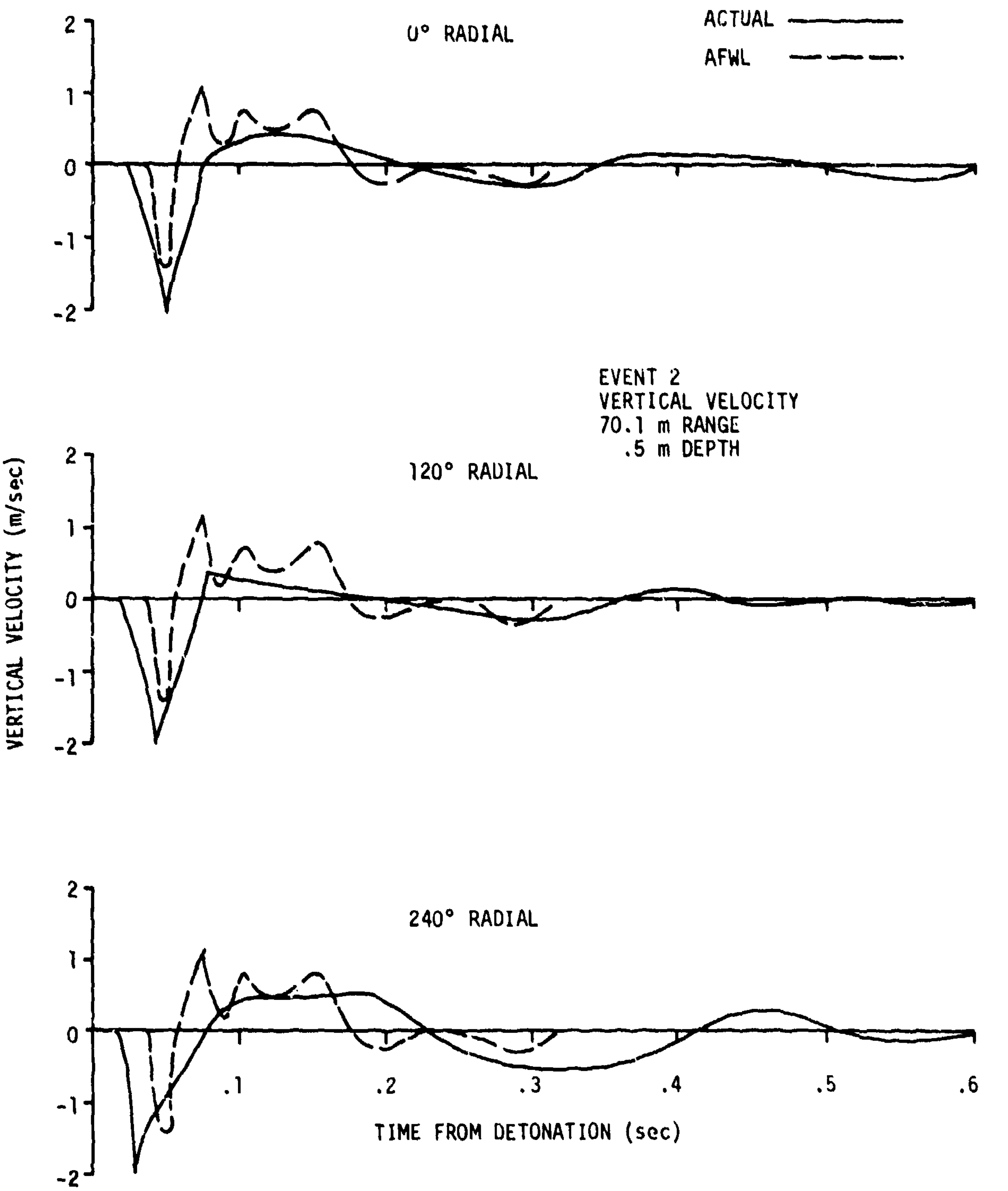


Figure 5.46. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

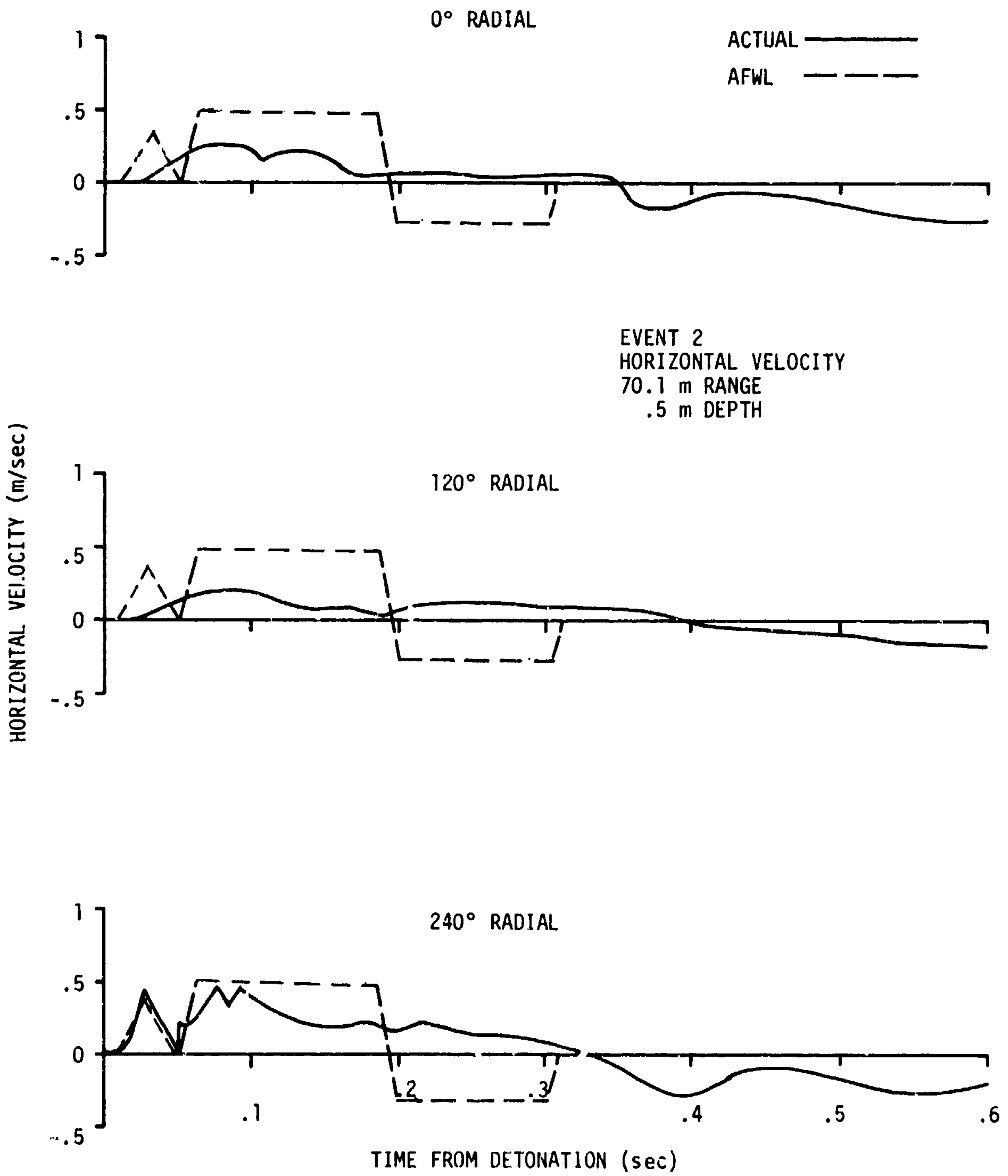


Figure 5.47. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

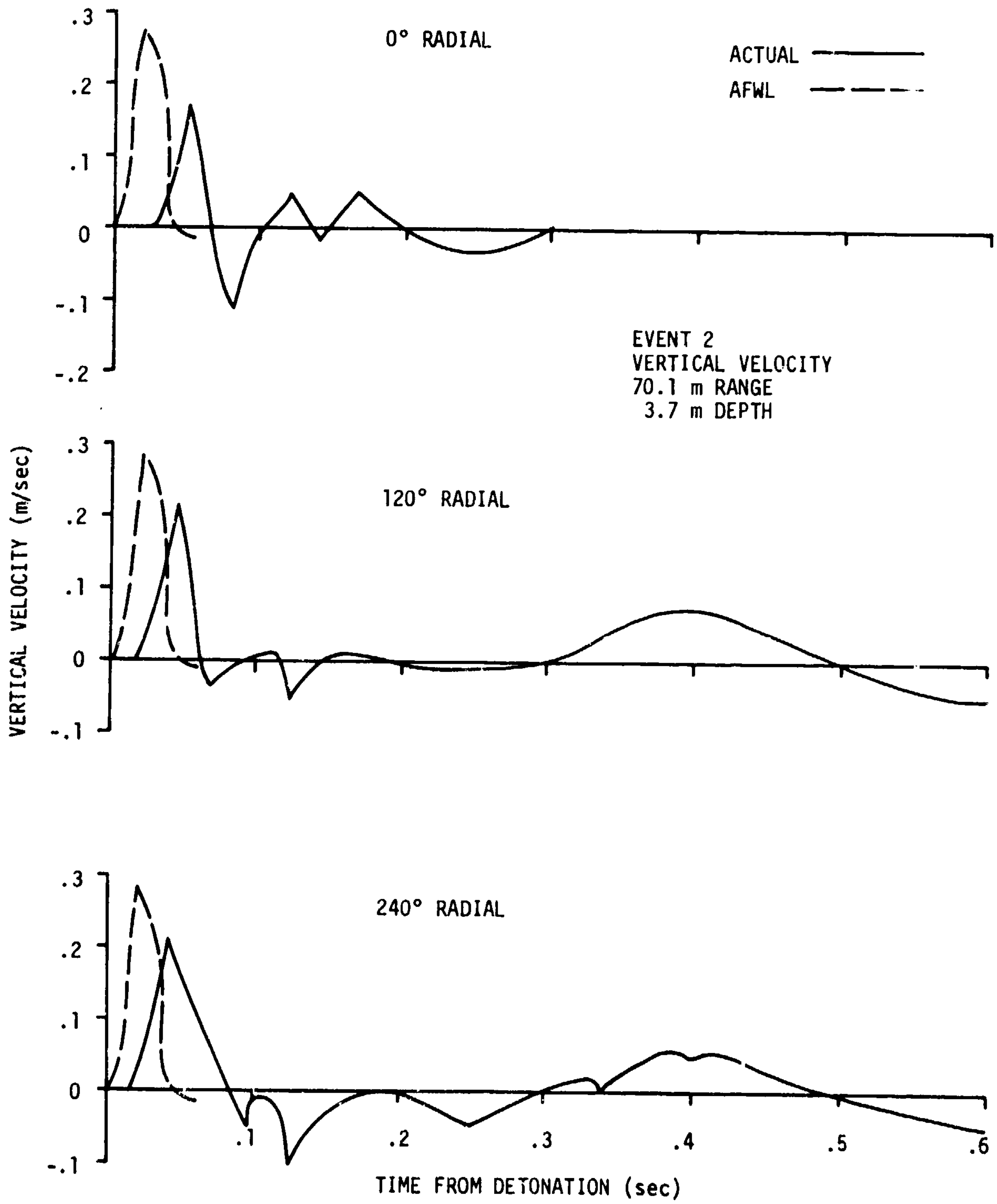


Figure 5.48. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

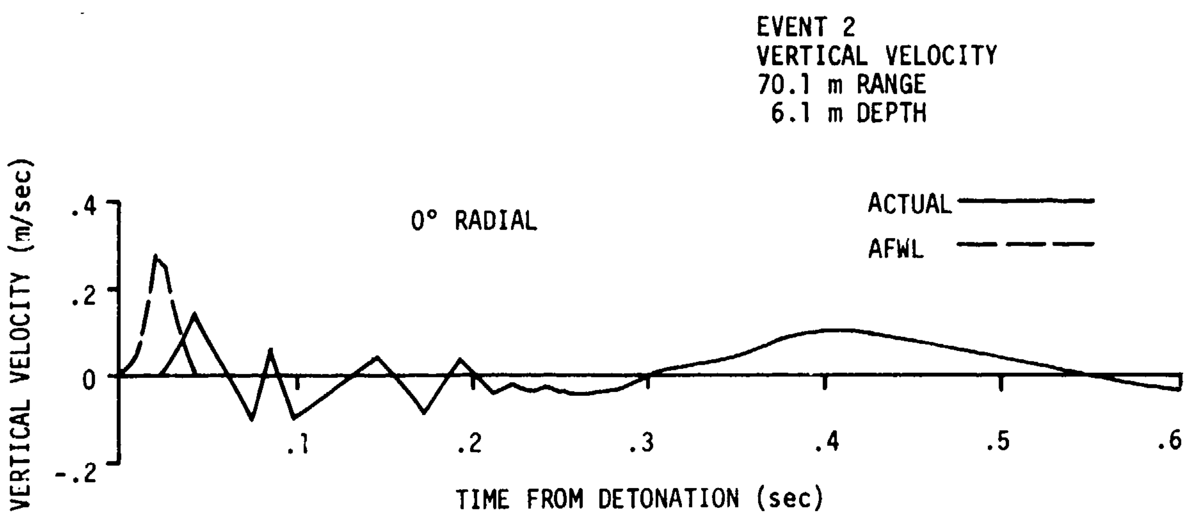


Figure 5.49. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

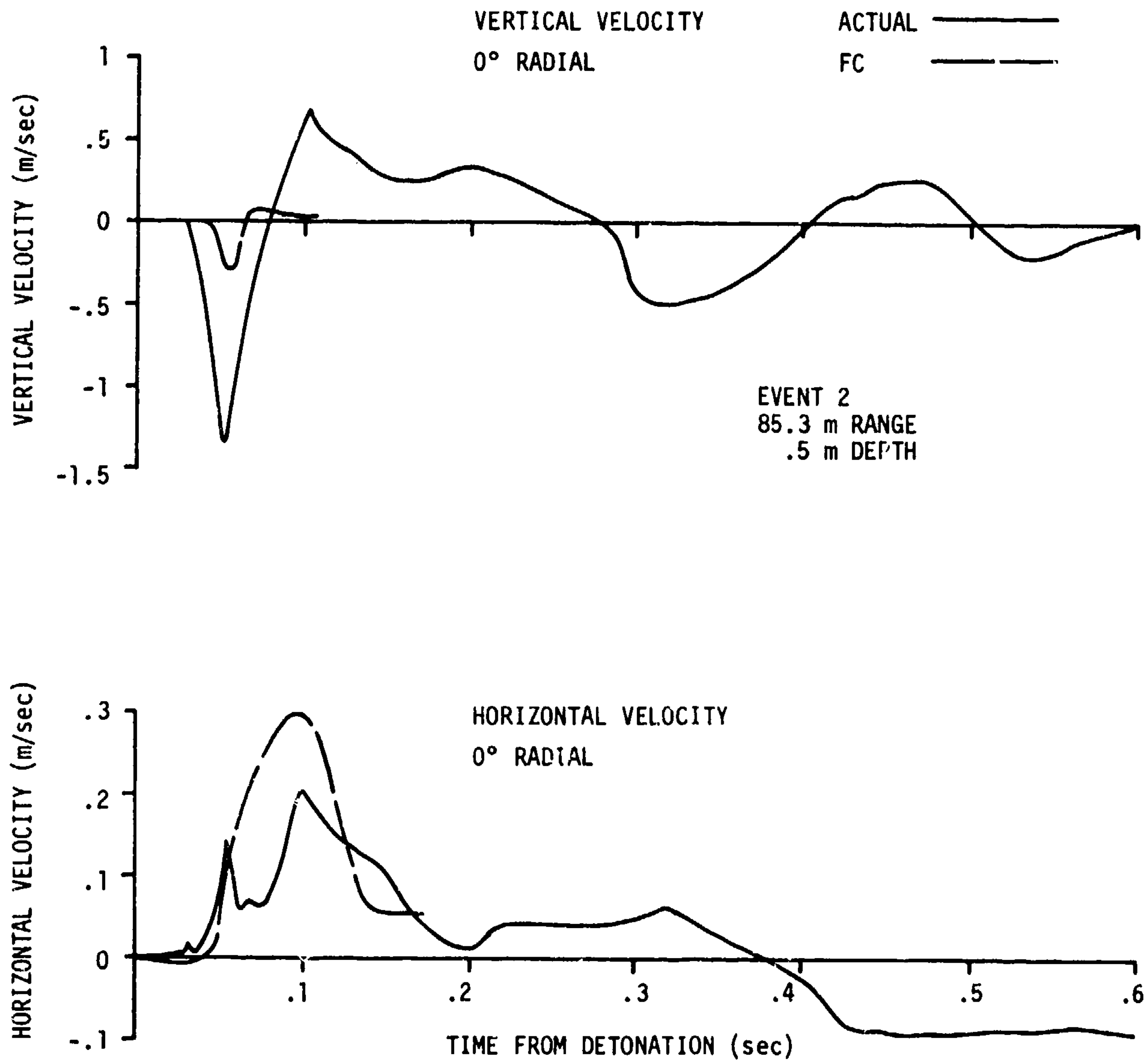


Figure 5.50. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

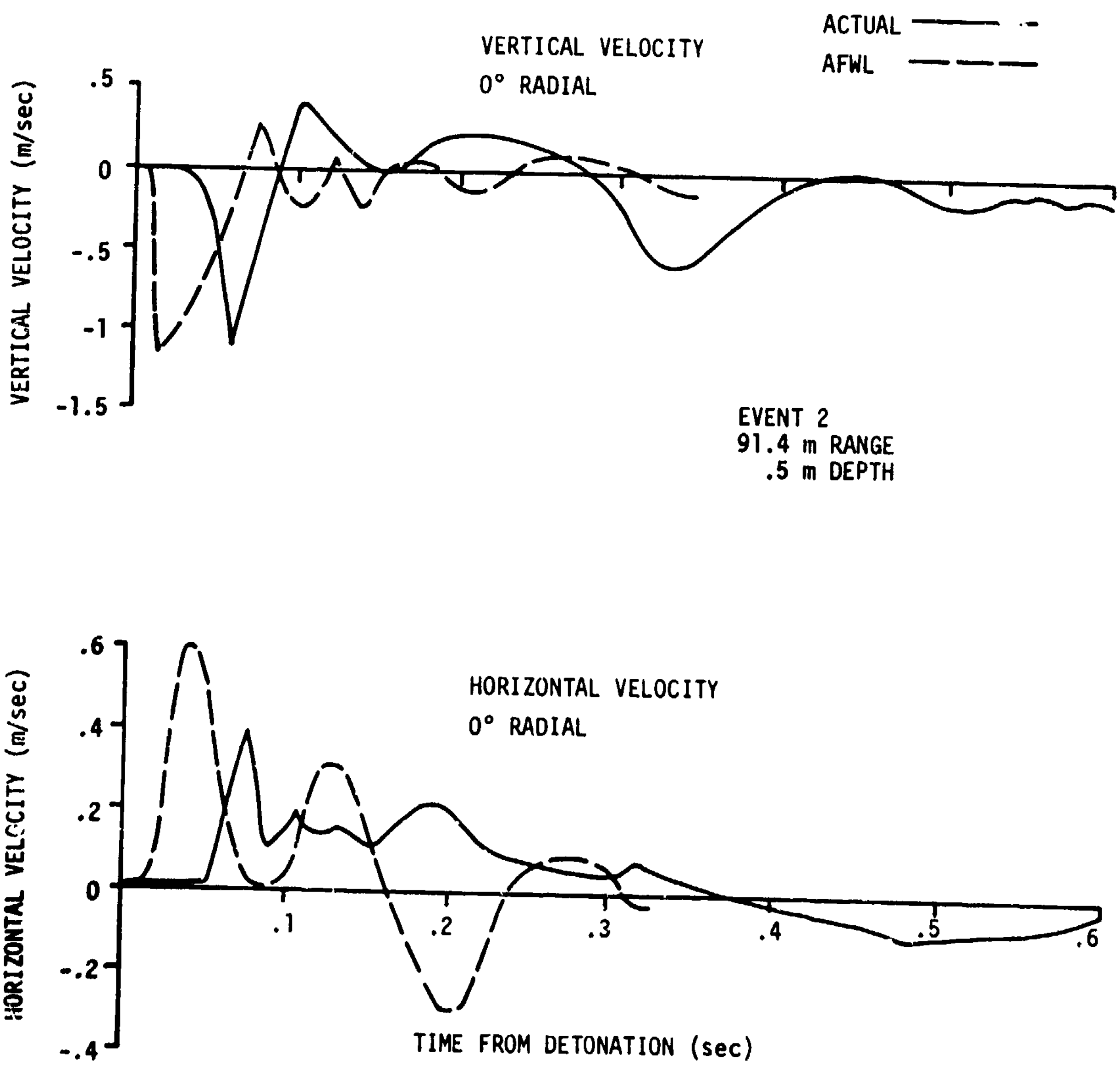


Figure 5.51. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

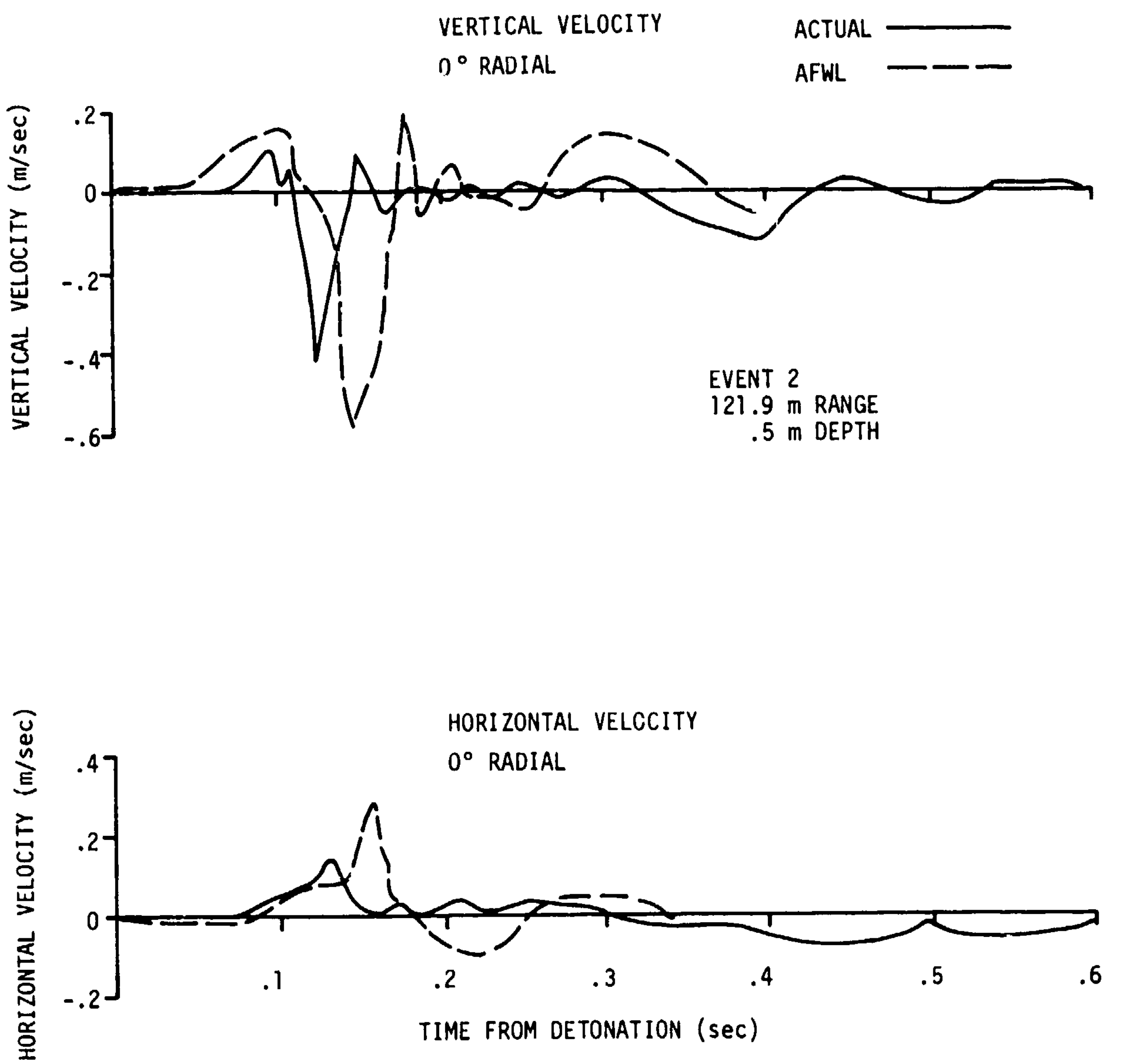


Figure 5.52. Velocity Waveforms and Predictions for Pre-DICE THROW II, Event 2

Table 5.4. Observations on Comparisons of AFWL Predictions with Event 2 Data

As compared to data from Event 2, the AFWL predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Airblast Induced or Negative Peaks	Reference Figures
Vertical Acceleration	-	(too few points for comparison)	5.3 - 5.6
Vertical Velocity	very close at 0.5 m depth (deviation 50% or less); higher beyond this depth (deviation -235% or less)	slightly higher at 0.5 m depth (deviation -50% or less); higher (deviation -200% or less) at greater depths	5.12 - 5.19
Horizontal Velocity	higher except at 91.4 m range, 0.5 m depth	-	5.20 - 5.25
Vertical Displacement	higher except at 48.8 m range, 9.1 m depth	mixed at 0.5 m depth; higher beyond this depth	5.26 - 5.33
Horizontal Displacement	higher at 0.5 m depth for all ranges except 91.4 m; higher at all other depths	-	5.34 - 4.39

Table 5.5. Observations on Comparisons of RDA Predictions with Event 2 Data

As compared to data from Event 2, the RDA predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Airblast Induced or Negative Peaks	Reference Figures
Vertical Velocity	generally lower at 0.5 m depth; higher at 1.8 m depth; mixed at all greater depths	lower at 0.5 m depth for all ranges; mixed at 1.8 m depth; higher at all greater depths	5.12 - 5.19
Horizontal Velocity	higher at ranges 33.5 to 70.1 m; lower at other ranges	-	5.20 - 5.25
Vertical Displacement	mixed at all stations	higher at 3.7 and 9.1 m depths; mixed at other depths	5.26 - 5.33
Horizontal Displacement	mixed at 6.1 m depth; higher at all other depths	-	5.34 - 5.39

Table 5.6. Observations on Comparisons of FC Predictions with Event 2 Data

As compared to data from Event 2, the FC/DNA predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Reference Figures
Vertical Velocity	very close (deviation 30% or less) but very few points	5.12 - 5.18
Horizontal Velocity	close (deviation 100% or less) but very few points	5.20 - 5.24

Table 5.7. Observations on Comparisons of WES Predictions with Event 2 Data

As compared to data from Event 2, the WES predictions were:

Type of Measurement	Direct Induced or Positive Peaks	Reference Figures
Vertical Acceleration	higher at depths to 1.8 m; generally lower at greater depths	5.1 - 5.6
Horizontal Acceleration	higher at 0.5 and 1.8 m depths; lower at greater depths	5.7 - 5.11
Vertical Velocity	higher at all depths except 9.1 m	5.12 - 5.19
Horizontal Velocity	generally higner at all ranges and depths	5.20 - 5.25

Table 5.8. Data versus Prediction Summary for Pre-DICE THROW II, Event 2

		AFWL	RDA	FC	WES
VERTICAL ACCELERATION:	DI	none	none	none	gen. less
	AI	less*	none	none	none
HORIZONTAL ACCELERATION:	DI	none	none	none	gen. less
VERTICAL VELOCITY:	DI	gen. greater	mixed	mixed	gen. greater
	AI	greater	mixed	none	none
HORIZONTAL VELOCITY:	DI	gen. greater	gen. greater	gen. greater	gen. greater
VERTICAL DISPLACEMENT:	DI	gen. greater	mixed	none	none
	AI	mixed	mixed	none	none
HORIZONTAL DISPLACEMENT:	DI	gen. greater	gen. greater	none	none

*less - means the predictions are less than the data

CHAPTER 6

COMPARISON OF EVENTS 1 AND 2 DATA

A small effort has been made to compare the experimental results of Event 1 with those of Event 2. Although much larger effort is justified in order to understand cratering phenomena, the scope of this analysis does not permit extensive consideration. Consequently, the present effort looks only at those aspects of comparison between the two events which might bear on predictive capabilities.

It might be expected that, because the charge yields were similar (however, the energy releases are not yet known), the far-field effects would also be similar. In that the charge configurations were different and the fireball photos revealed a somewhat different early-time development in the two cases, different near-field effects may be expected. The craters were indeed measurably different.

The water table roughly defined the interface between low and high wave propagation velocity layers, as described in Chapter 1. Because the crater of Event 1 penetrated the water table, it is clear that a significant part of the blast energy was injected into the lower layer. The reverse was true for Event 2, in which less energy was injected into the lower layer and the crater was broader and shallower. These comments are qualitatively supported by observations from the data as indicated in Table 6.1.

More detail is available in the illustrations of Figures 6.1 through 6.17. Although the data is scant, it can be seen that measurements are in most cases very similar for the two shots. In a few cases, notably the air-induced vertical velocities at 1.8 m depth (the negative peaks shown in the lower half of Figure 6.6), the discrepancies in measurement are large. A comparable effect at the same ranges at the shallower depth (0.5 meter) is not observed. Because Events 1 and 2 were not at the same site, this anomaly could be one of geology. The horizontal velocity data at these same stations (Figure 6.9), however, shows far less divergence between Events 1 and 2.

It is possible that an instrumental problem could be responsible for the differences.

In summary, the differences detectable in ground motion measurements far from the craters of Events 1 and 2 are minor, except in a few cases. Measurements in the vicinity of the craters should show differences due to charge shape. Comparison of Figures 4.17 with 5.13 and 4.34 with 5.27 illustrates a slightly better predictive capability for the tangent sphere (Event 1) charge configuration, although there is not enough data to draw a strong conclusion. In these cases, predictions (by RDA) were based on scaling data from tests which were of the tangent sphere configurations. Better predictive methods, or a more extensive data base for configurations other than the tangent sphere, may be needed to distinguish charge shape effects.

Table 6.1. Observations on Comparisons of Data from Events 1 and 2

As compared to data from Event 2, the data from Event 1 are:

Type of Measurement	Direct Induced or Positive Peaks	Airblast Induced or Negative Peaks
Vertical Acceleration	lower above water table; higher below water table	lower above water table; higher below water table
Horizontal Acceleration	lower above water table; higher below water table	not determined (too few points)
Vertical Velocity	lower above water table; higher below water table	higher above water table; lower below water table
Horizontal Velocity	close except at ranges of 33.5 m or less	close
Vertical Displacement	lower above water table; higher below water table	close (very few points)
Horizontal Displacement	close except at ranges of 33.5 m or less	not determined (too few points)

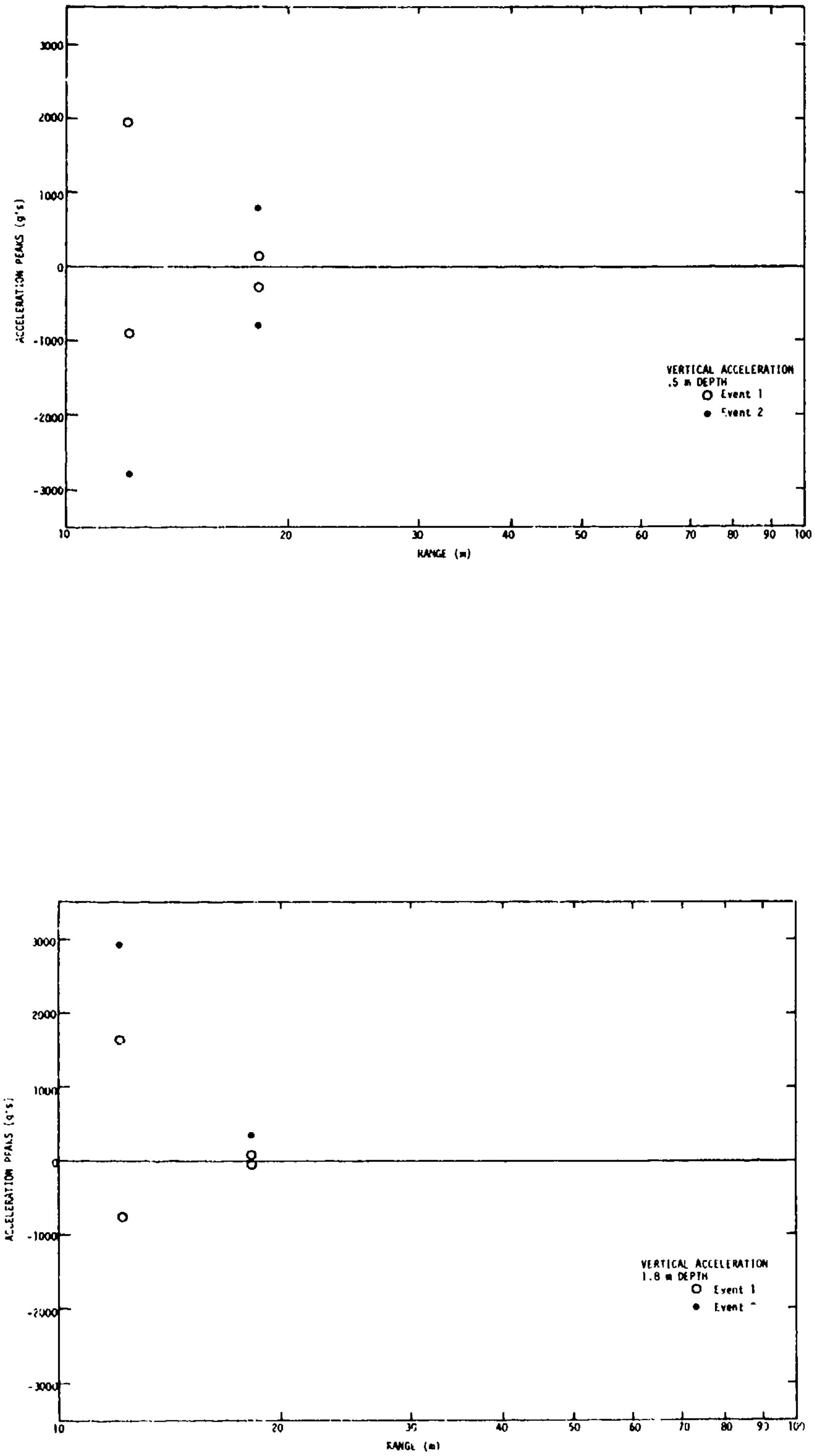


Figure 6.1. Vertical Acceleration vs. Range for Pre-DICE THROW, Events 1 and 2

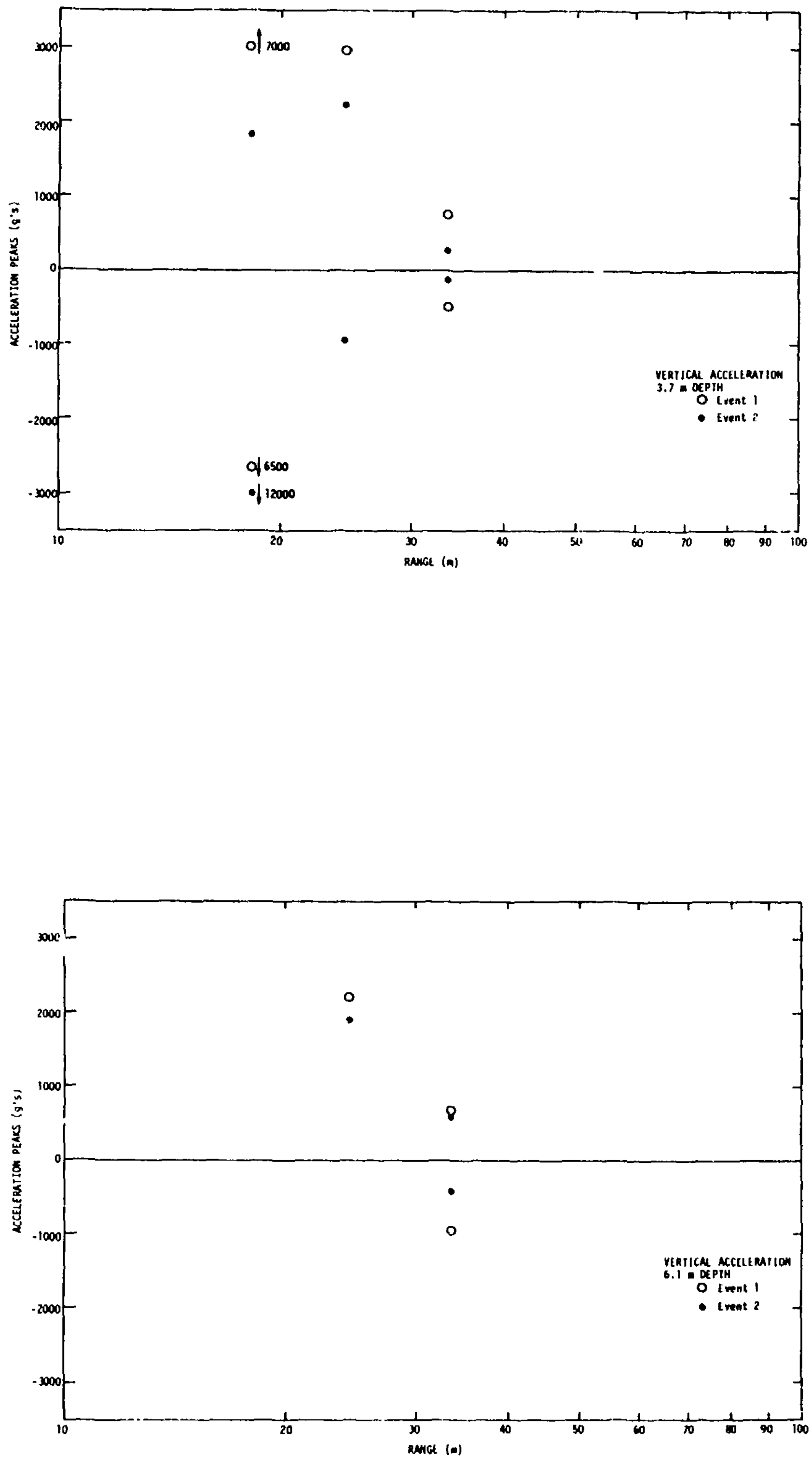


Figure 6.2. Vertical Acceleration vs. Range for Pre-DICE THROW, Events 1 and 2

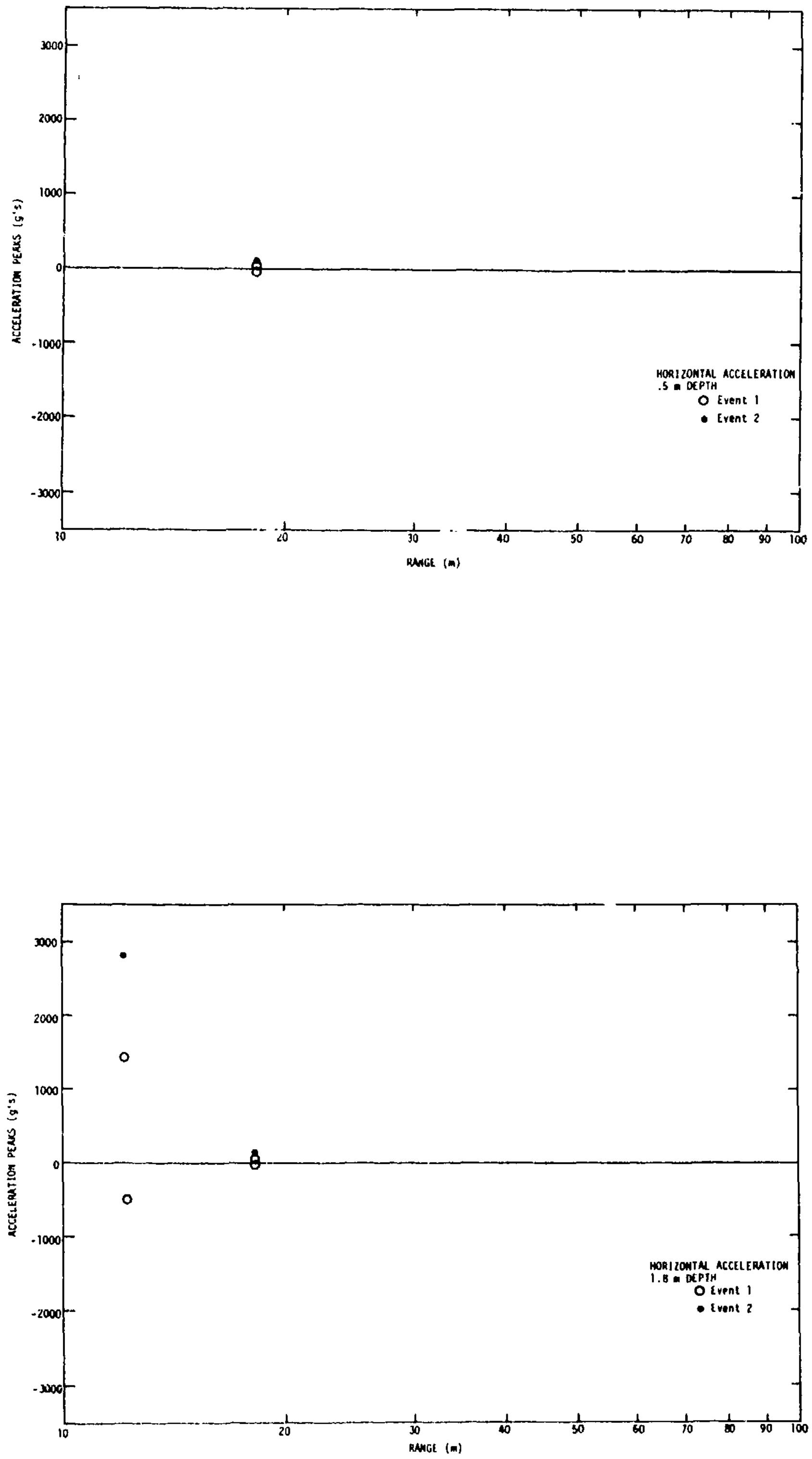
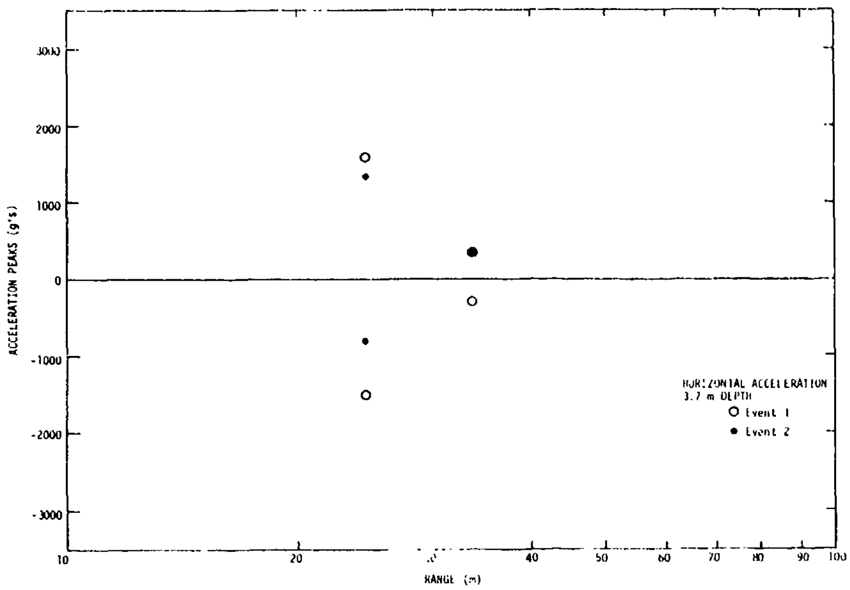


Figure 6.3. Horizontal Acceleration vs. Range for Pre-DICE THROW, Events 1 and 2



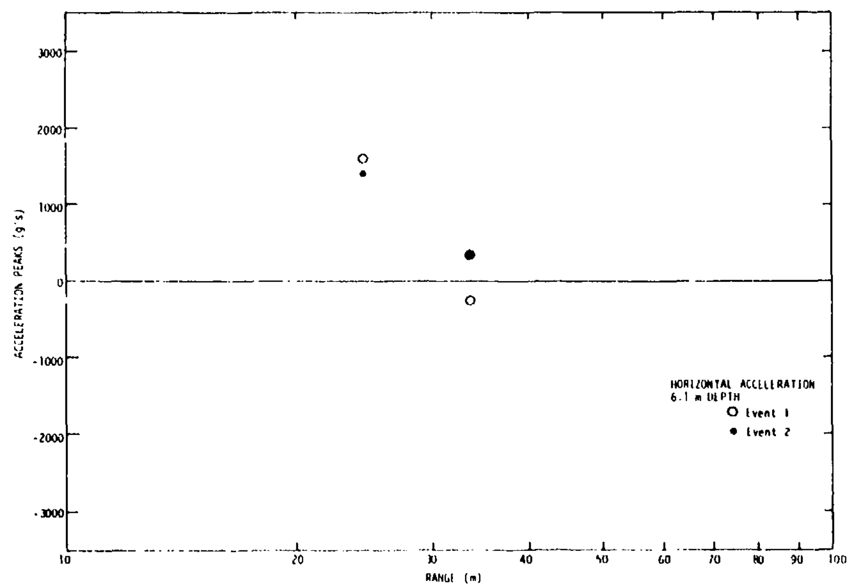


Figure 6.4. Horizontal Acceleration vs. Range for Pre-DICE THROW, Events 1 and 2

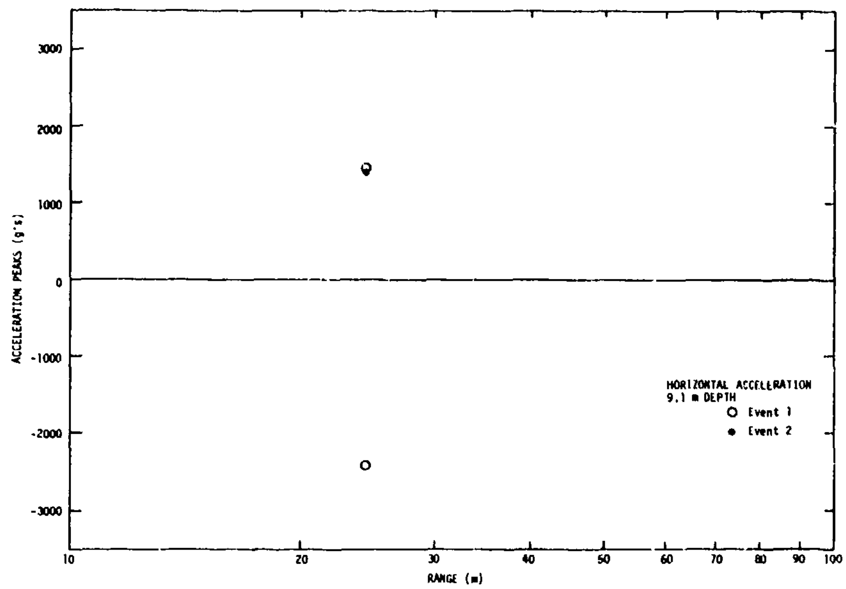


Figure 6.5. Horizontal Acceleration vs. Range for Pre-DICE THROW, Events 1 and 2

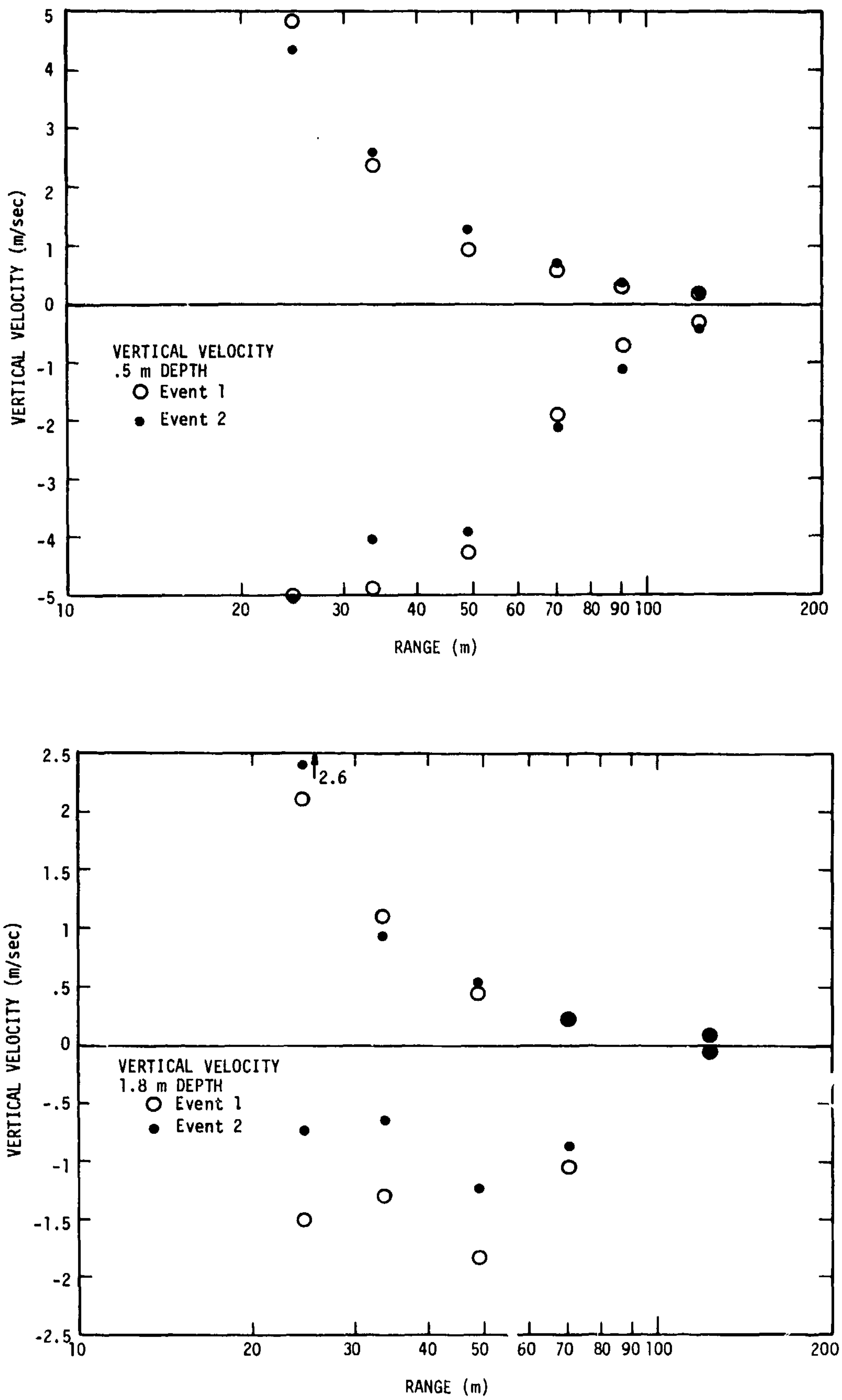


Figure 6.6. Vertical Velocity vs. Range for Pre-DICE THROW, Events 1 and 2

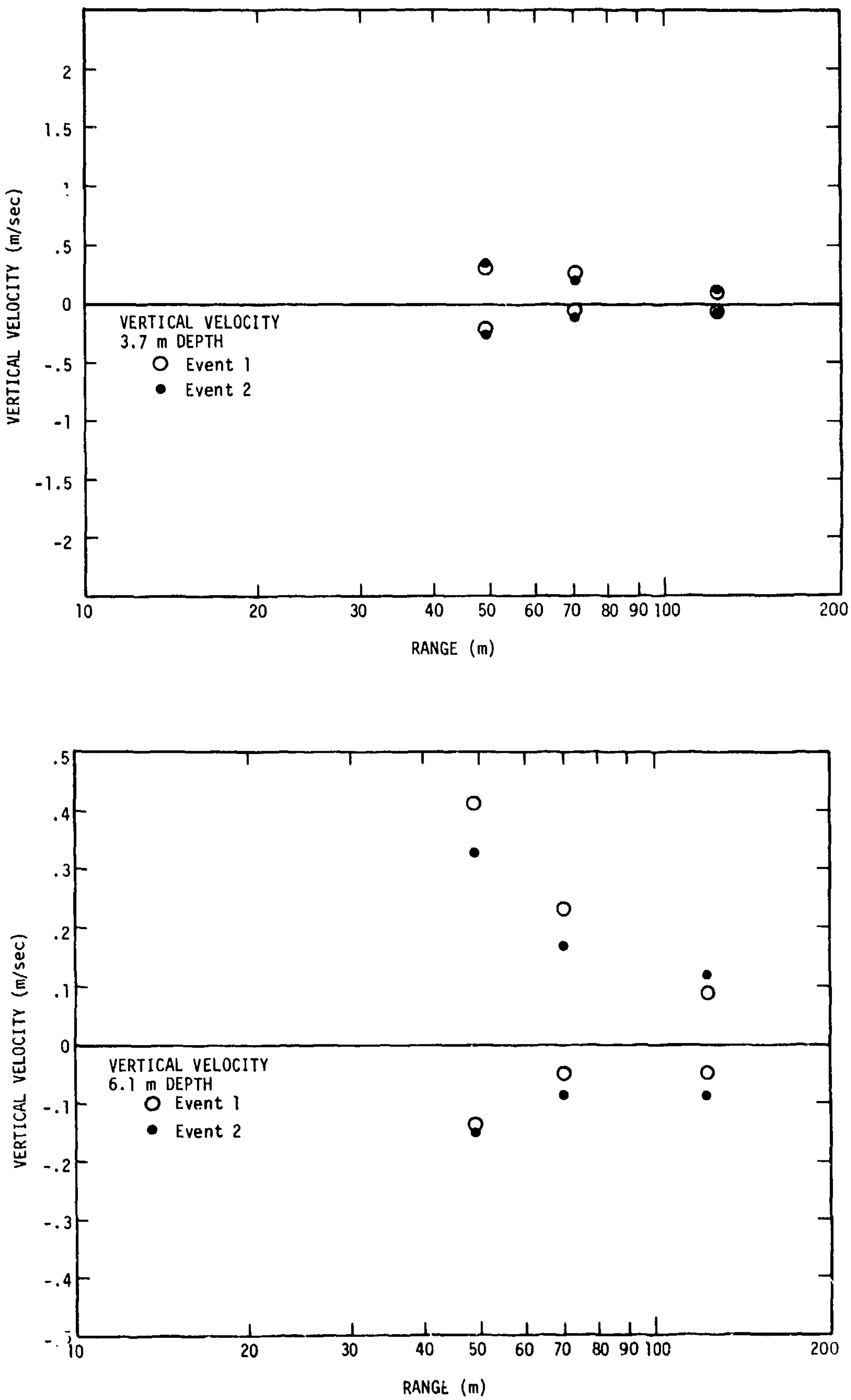
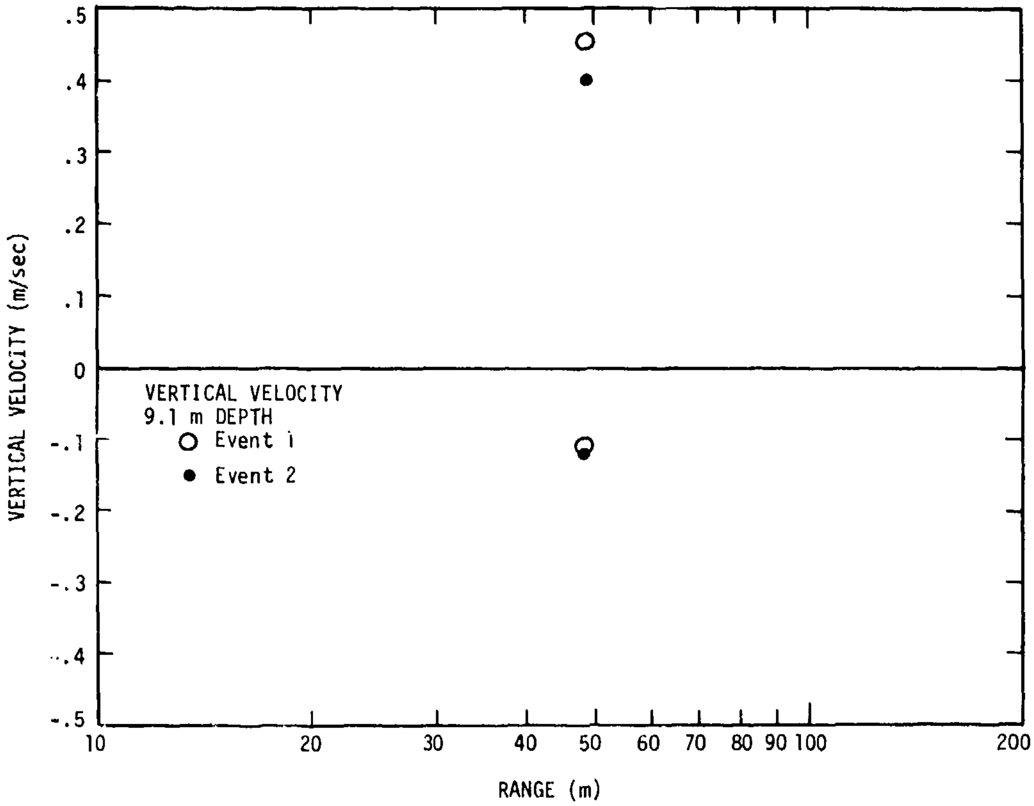


Figure 6.7. Vertical Velocity vs. Range for Pre-DICE THROW, Events 1 and 2



. igure 6.8. Vertical Velocity vs. Range for Pre-DICE THROW, Events 1 and 2

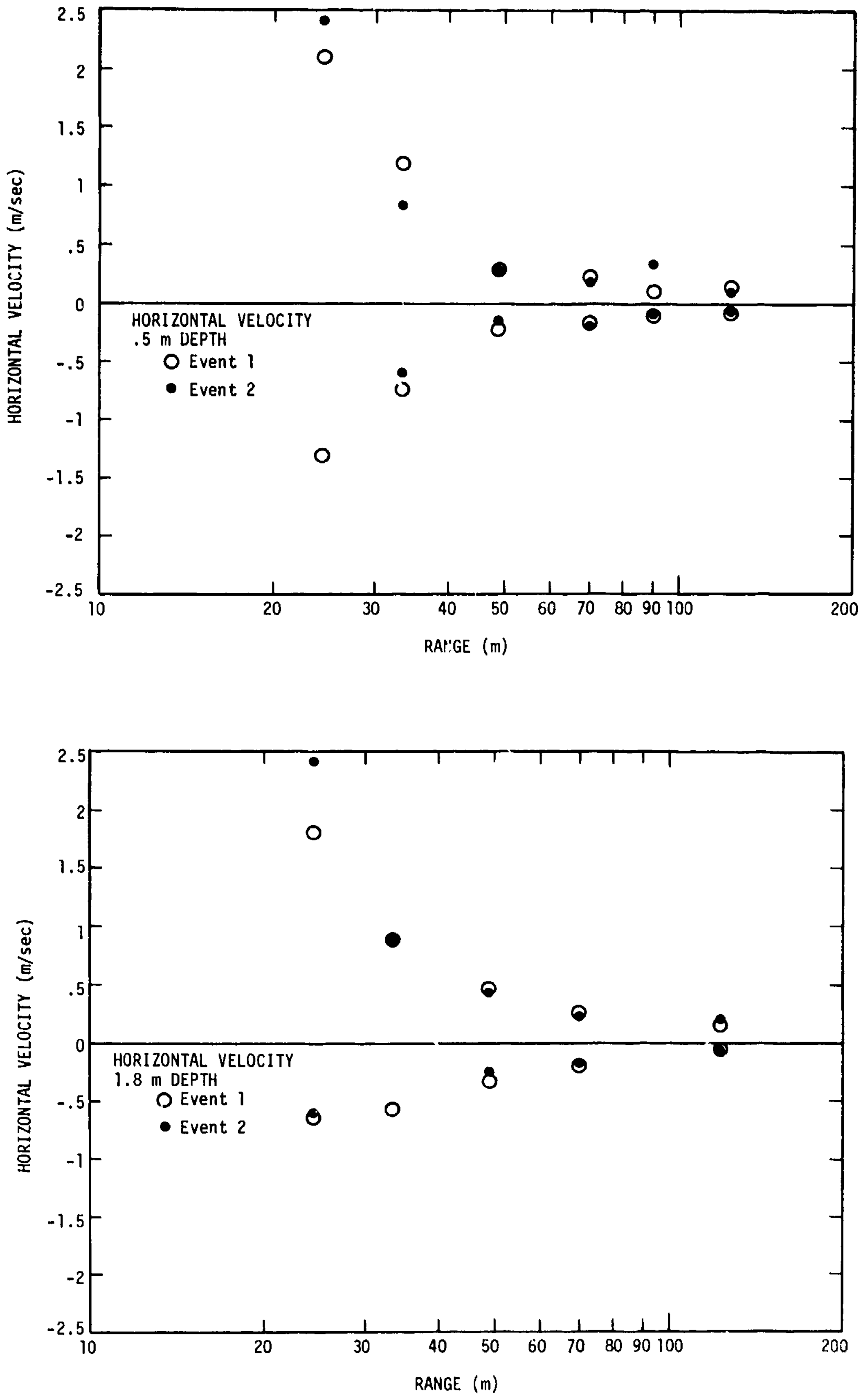


Figure 6.9. Horizontal Velocity vs. Range for Pre-DICE THROW, Events 1 and 2

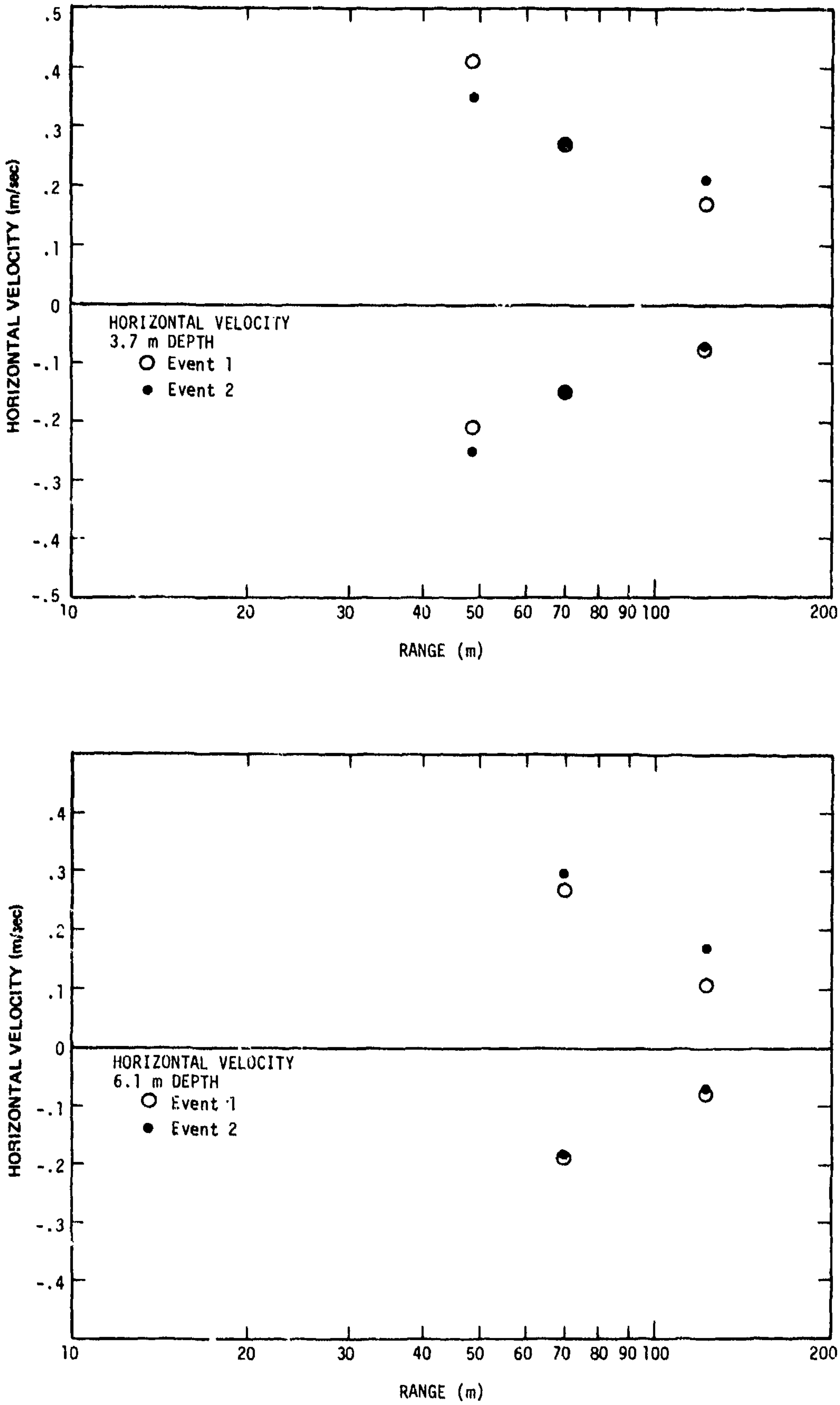


Figure 6.10. Horizontal Velocity vs. Range for Pre-DICE THROW, Events 1 and 2

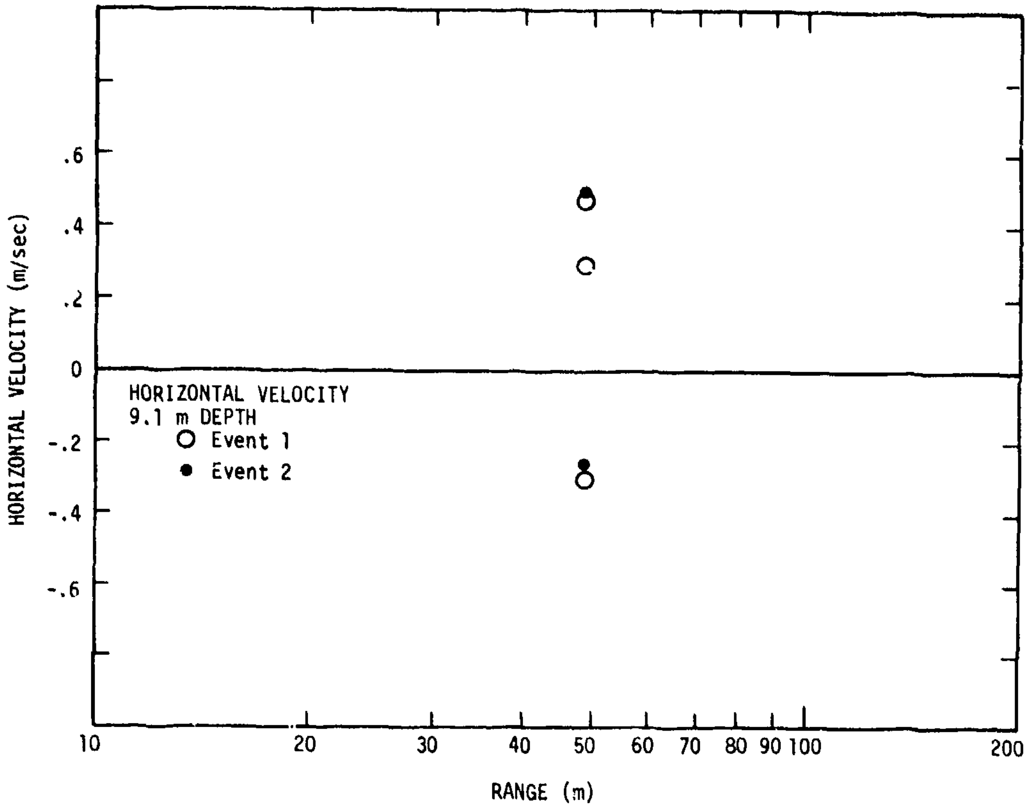


Figure 6.11. Horizontal Velocity vs. Range for Pre-DICE THROW, Events 1 and 2

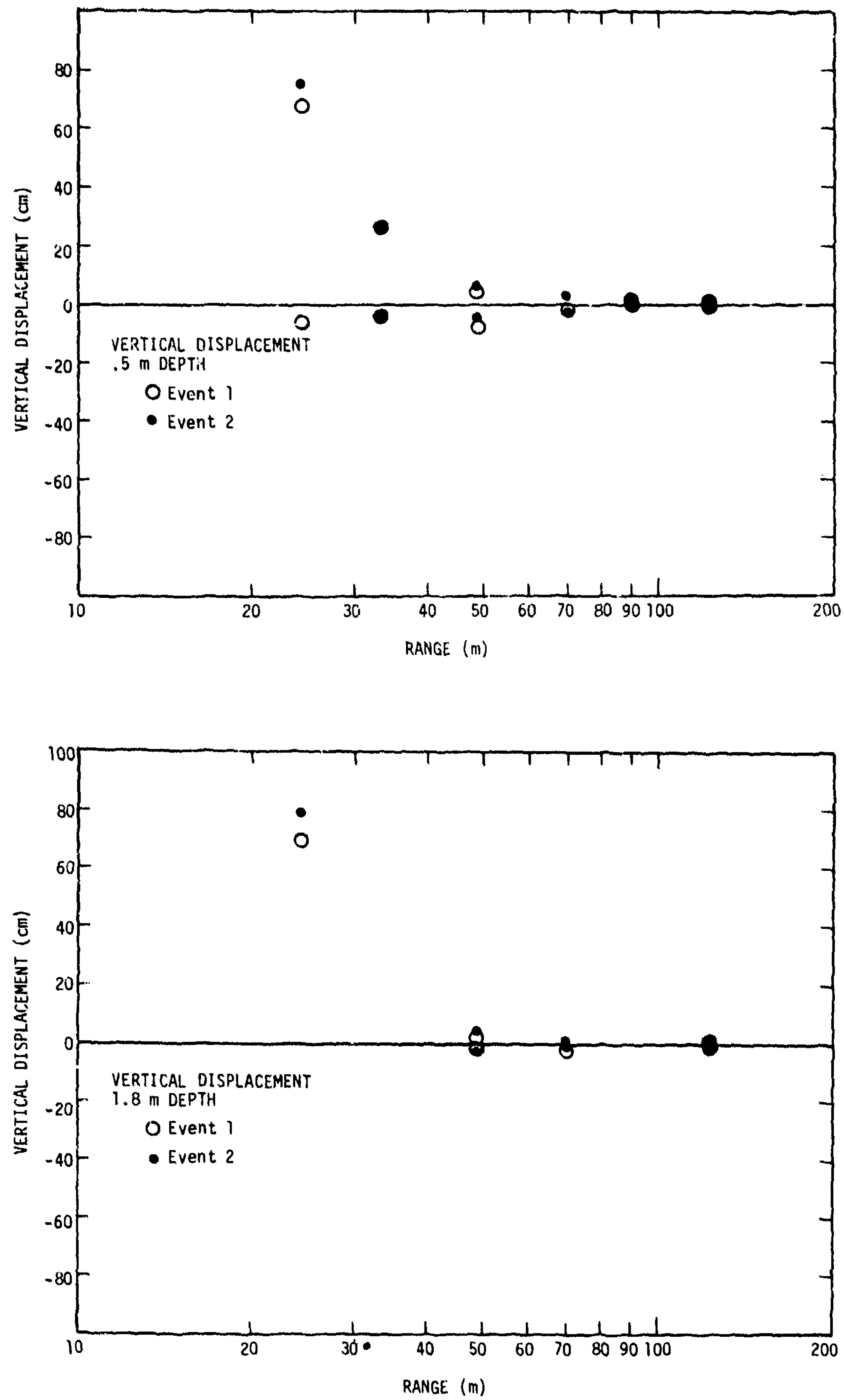
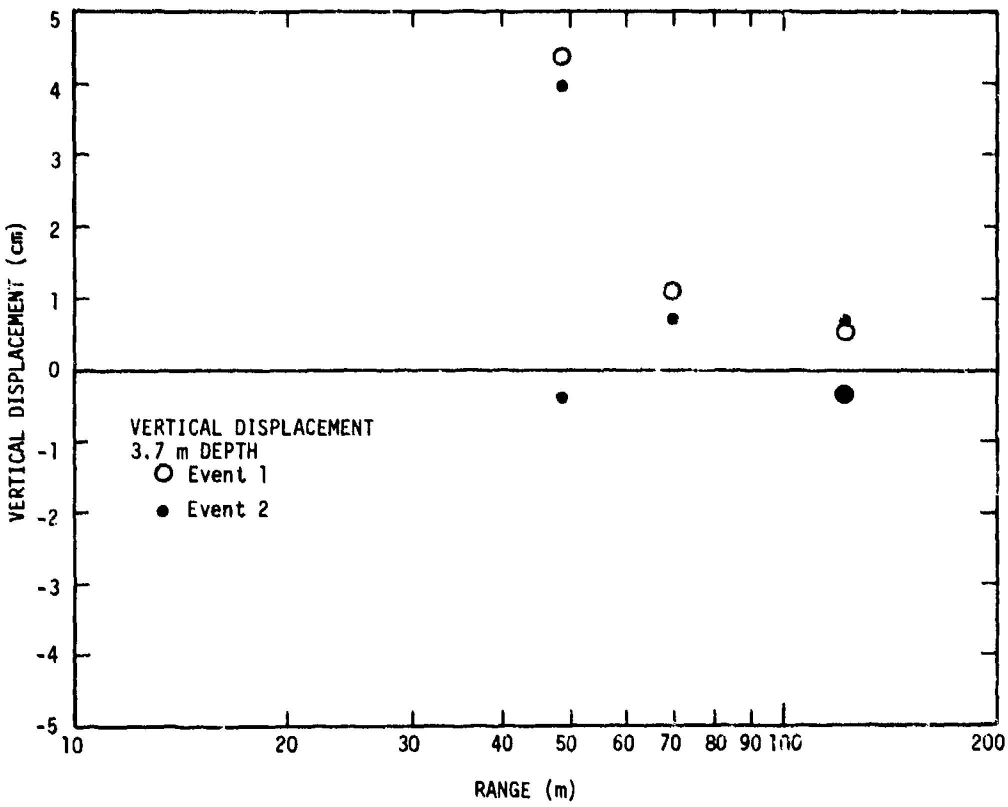


Figure 6.12. Vertical Displacement vs. Range for Pre-DICE THROW, Events 1 and 2



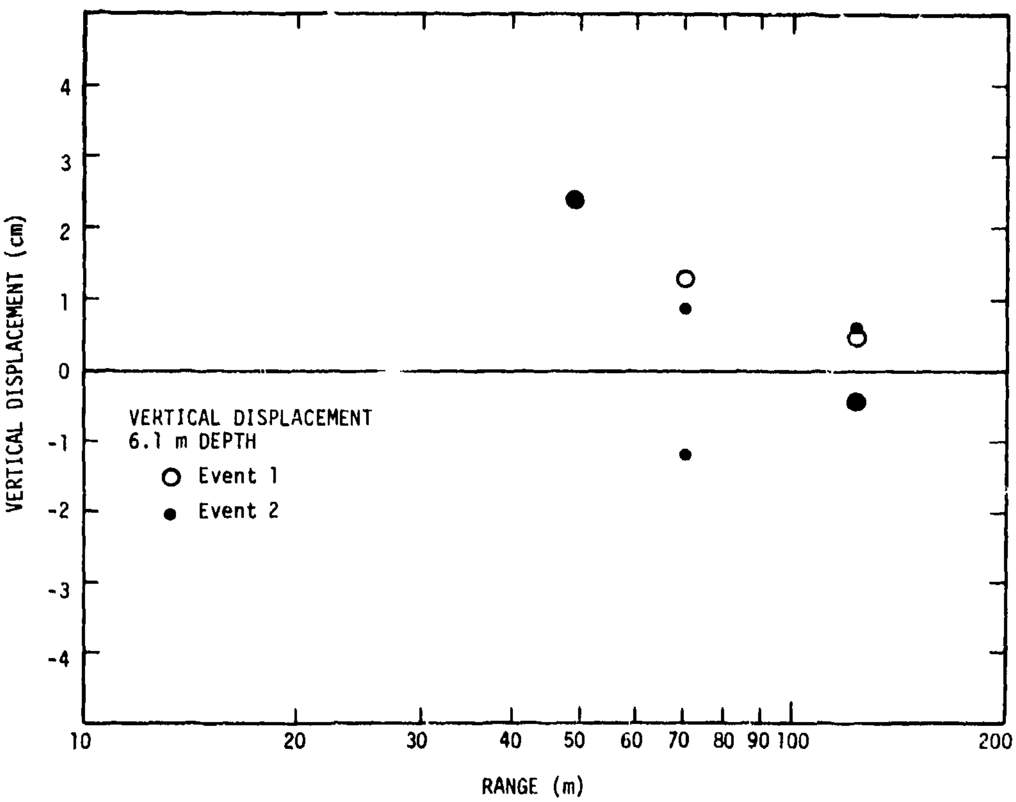


Figure 6.13. Vertical Displacement vs. Range for Pre-DICE THROW, Events 1 and 2

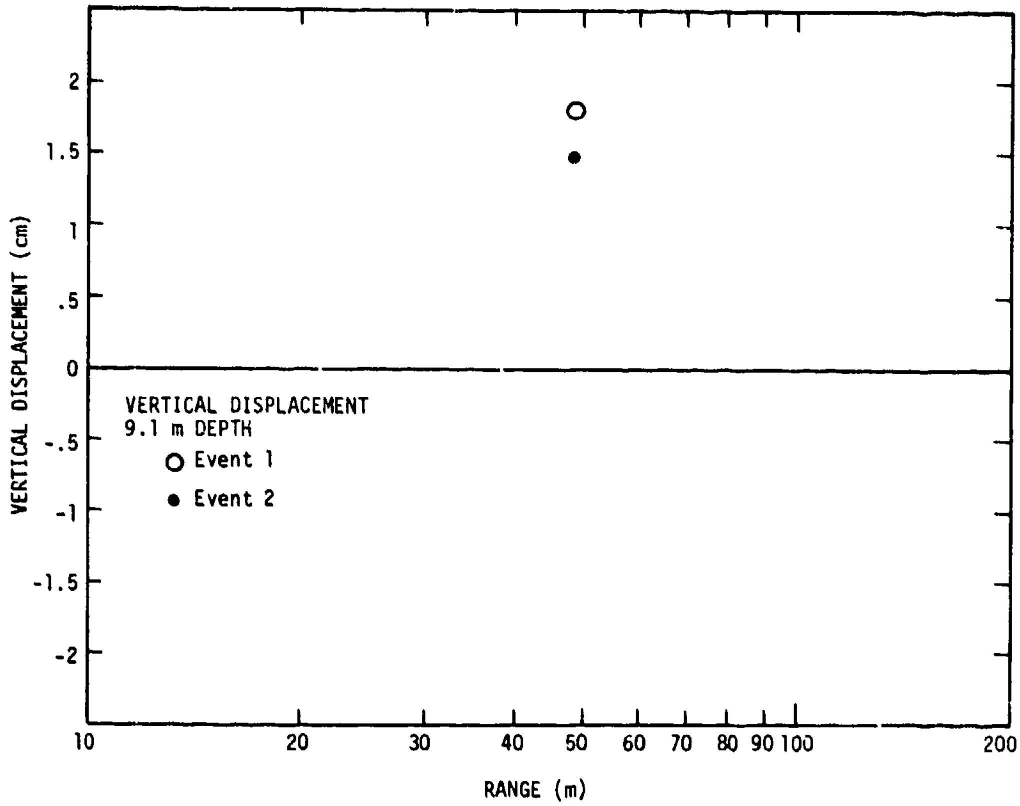
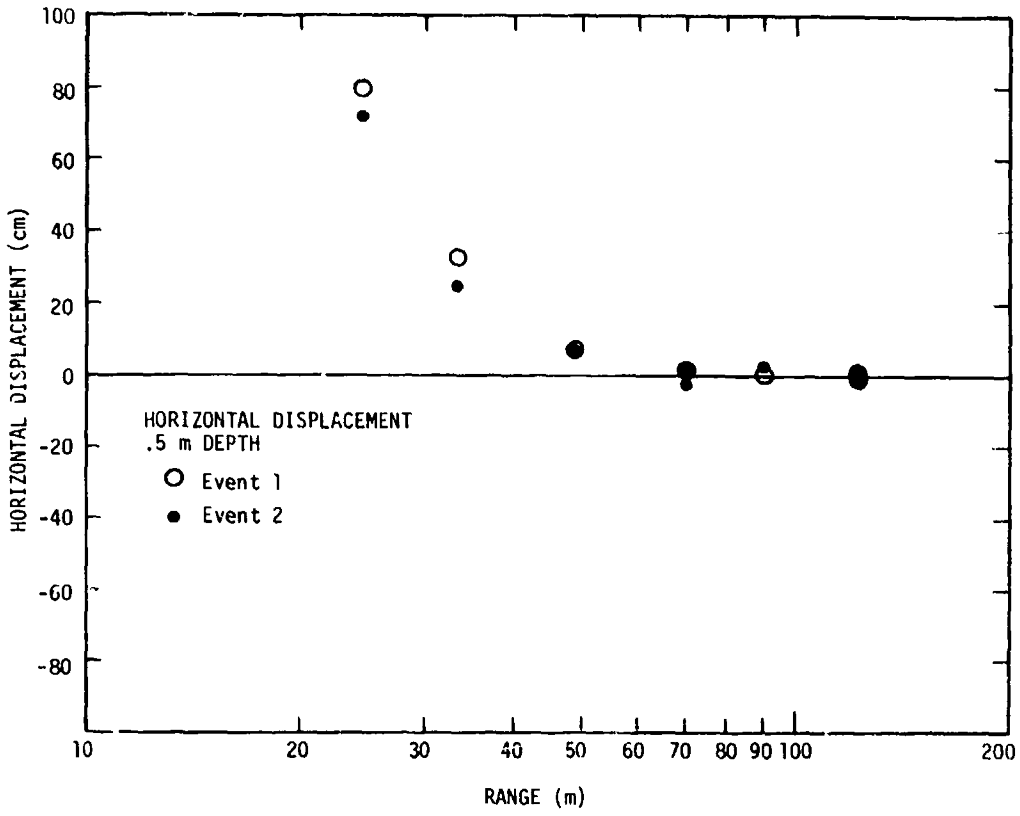


Figure 6.14. Vertical Displacement vs. Range for Pre-DICE THROW, Events 1 and 2



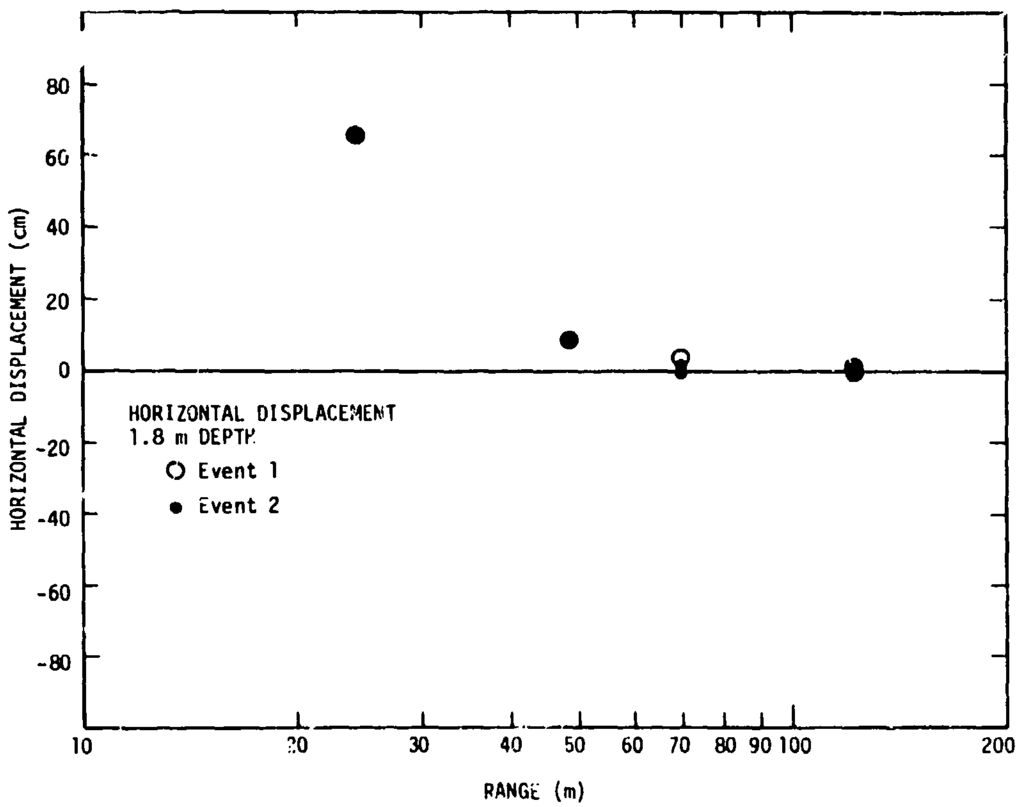


Figure 6.15. Horizontal Displacement vs. Range for Pre-DICE THROW, Events 1 and 2

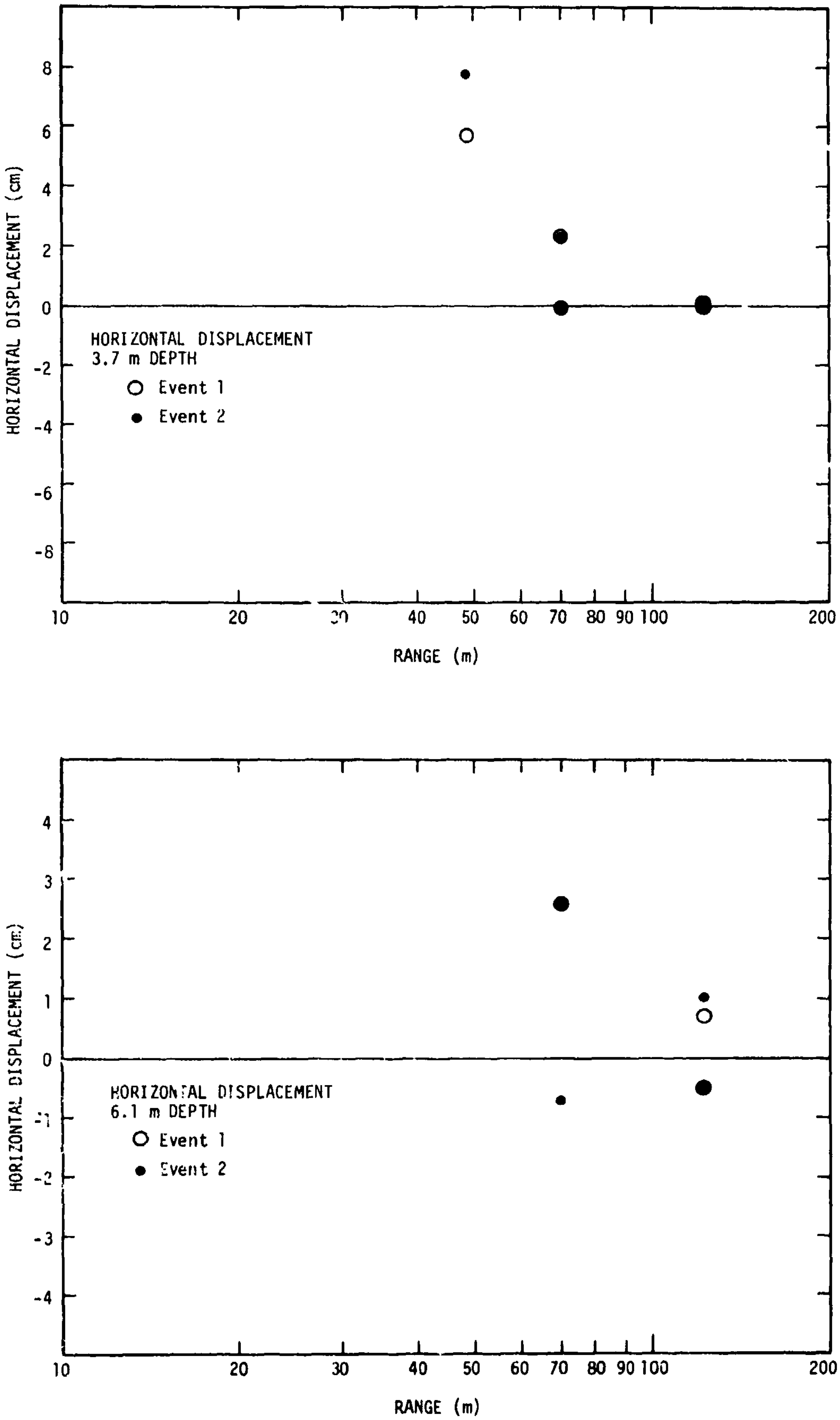


Figure 6.16. Horizontal Displacement vs. Range for Pre-DICE THROW, Events 1 and 2

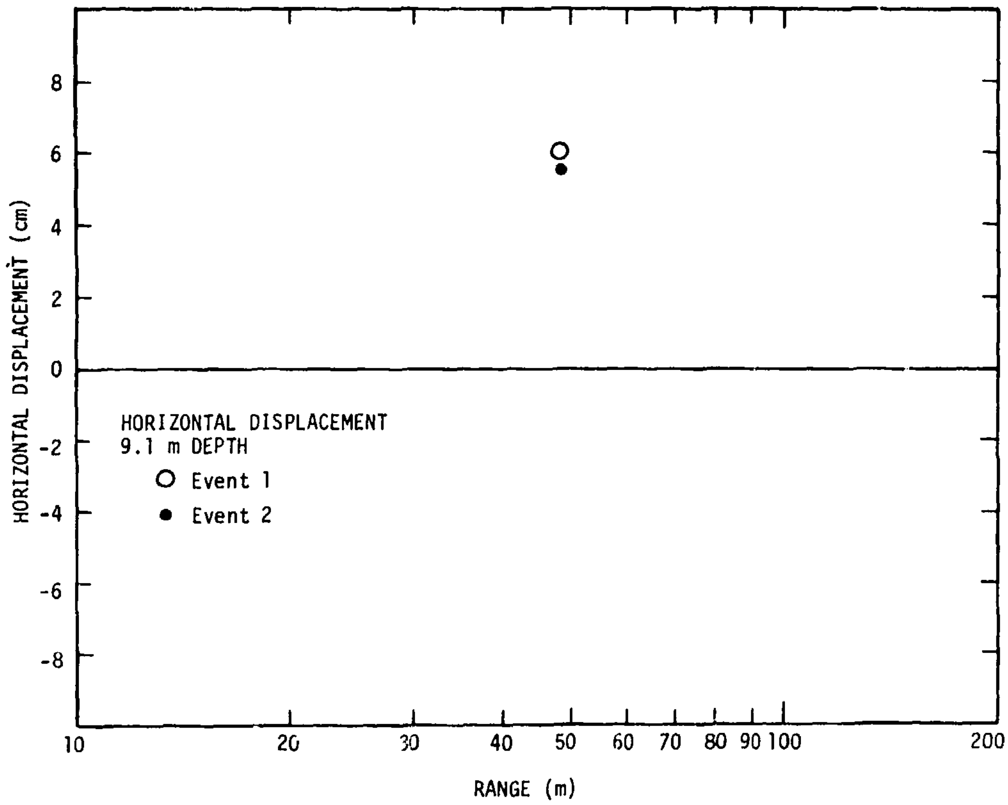


Figure 6.17. Horizontal Displacement vs. Range for Pre-DICE THROW, Events 1 and 2

CHAPTER 7

ANALYSIS AND CONCLUSIONS

A. INTRODUCTION

The objective of this report was to compare and to evaluate, if possible, the several prediction techniques. Casual inspection of the results does not provide a clear-cut answer to the question of which technique most accurately predicted the results obtained. A more quantitative approach, using some simple statistical methods, is attempted in this chapter. The data base does not really support a statistical analysis, but casting the numbers in statistical terminology does provide a familiar and useful approach to comparisons.

In making the analysis, the particle velocity data are used because these measurements are numerous, are of good quality, and are relatively easy to interpret. There is, however, a limitation which affects the validity of the present discussion. In reading the data traces, the main positive and negative peaks (one each) were read. For the vertical velocity components, these peaks invariably occurred within the first 100 milliseconds of the trace, and corresponded respectively to the leading edges of the air- and direct-induced motions. For the horizontal velocity components, however, the situation is not so easily interpreted. The inclination of the air- and direct-induced waves close-in to the burst is very large and the horizontal or radial components of the particle motion are therefore relatively small. Also, both air- and direct-induced motions are in the outward, or positive, direction. Consequently the peaks read were frequently due not to air- and direct-induced motions, but to another type of wave, the surface wave (probably of the Raleigh type) which results from sudden depression of the ground at the burst point. These peaks invariably occur farther out in time, typically at 200 - 300 milliseconds. Seen on the traces, the slow undulations of the surface waves are easy to recognize. In the tables, it cannot be determined whether a given peak value arose from airblast-induced, direct-induced, or surface wave motions.

The long duration surface wave motions were more significant in these events than had been anticipated for data analysis. Beyond a range of about 50 meters, however, there is a tendency for the peak values of the induced waves to dominate the peaks of the surface waves. Nevertheless, it is still not possible to distinguish entries in the tables according to whether they are air- or direct-induced. Consequently, we believe it is impractical to make prediction comparisons on the basis of horizontal peak values until the data is rescanned under the selective intent to pick out the airblast- and direct-induced peaks.

The vertical velocity peaks, as previously explained, can almost always be interpreted unambiguously. There are a few cases where identification of the wave could be in doubt, but these cases will probably not comprise a significant fraction of the total. Hence in the present analysis, the vertical velocity peaks will be used as given.

Most of the measurements on Events 1 and 2 were taken in the low velocity layer where the "X" discussed in Chapter 1 is found. Consequently they are typical of regions where both air- and direct-induced waves are important. If the first peak is negative, the air-induced wave arrived first, and if the first peak is positive, then the direct-induced wave arrived first. One of the important tasks of the prediction efforts was to try to estimate the contributions of these two waves individually. Therefore, the vertical velocity data are ideally suited to the analysis undertaken here. It will be obvious that the analysis is far from exhaustive, and that a re-reading of the data traces, together with a more sophisticated analytical approach, would undoubtedly achieve more authoritative results.

B. SIMPLE AVERAGES OF PERCENT DEVIATIONS

We look first at simple averages of the percent deviations appearing in Chapters 4 and 5 to try to find trends in the easiest way. The data to be used are the observed peak values compared to the predicted peak values, called "percent deviations" and computed from

$$\text{Percent Deviation } (\eta) = \frac{\text{Average Experimental Value - Prediction}}{\text{Average Experimental Value}} \times 100$$

As a statistical variable, η is unusual because its positive range is truncated; that is, all positive values must fall between 0 and 100 while the negative values are distributed between 0 and $-\infty$. Consequently using these data leads to somewhat skewed averages, especially when there are numerous values in the sample of magnitude less than -100. The small sample does not justify a more careful analysis, however. For our purposes, we believe simple comparisons are sufficient to draw the conclusions called for.

The simple averages of the percent deviations are computed in the following fashion:

$$\bar{\eta} = \frac{1}{n} \sum_{i=1}^{n} \eta_i$$

where the η_i are the percent deviations at all depths for a given range, and the sign of η_i is taken into account. The results are given in Tables 7.1 and 7.2. The Field Command predictions were not used in this analysis because the number of available predictions was so small.

One sees, first, a preponderance of negative values, which signifies a tendency to overestimate the magnitude of the motions. This tendency seems to increase with range. An exception is RDA's predictions of the DI peak values, for which the averages of the deviations are nearly all positive. The stated purpose of the WES predictions, as mentioned earlier, was for gage ranging, which requires a safe overestimate in order to avoid loss of data. Therefore, the WES averages are all negative, as they should be.

Second, one observes that magnitudes of almost all the $\bar{\eta}$ are greater than 50%. In other words, the probability of predicting ground

Table 7.1. Averages of Percent Deviations at Constant Ranges for Vertical Velocity Predictions; Event 1

Range (m)	AFWL		WES	RDA	
	DI	AI	DI	DI	AI
24.4	-36.1	-12.1	-46	27.5	28.7
33.5	-	-	-48.5	29.6	-39.5
48.8	-280	-134	-65.8	3.1	-143
70.1	-57.4	-268	-58.3	3.0	-161
91.4	-91.5	-126	-75.0	1.4	-126
121.9	-89.5	-73.9	-109	6.4	-198
182.9	-	-	-415	-67.4	-44.5

Table 7.2. Averages of Percent Deviations at Constant Ranges for Vertical Velocity Predictions; Event 2

Range (m)	AFWL		WES	RDA	
	DI	AI	DI	DI	AI
24.4	29.1	-9.2	-34.3	32.3	-4.9
33.5	-	-	-74.0	19.1	-4.4
48.8	-104	-35.8	-139	8.5	-28.5
70.1	-91.5	-108	-80.2	-11.2	-50.3
91.4	-	-5.5	-22.5	42.5	44.5
121.9	-70.5	-15.4	-135	-10.8	-94.1

motion peaks accurately is, on the average, no better than 50%. A more sensitive measure of this quantity is, however, shown in the next section.

C. STANDARD DEVIATIONS

The above simple averages do not really provide enough insight into the accuracy of the predictions so we now examine standard deviations. The statistical deviation of the members of a set from the centroid of the set is an approved measure of the scatter, or of the accuracy in this case, of the members of the set. We again calculate simple averages of the percent deviations appearing in Chapters 4 and 5 from the expression:

$$\bar{\eta} = \frac{1}{n} \sum_{i=1}^{n} \eta_i$$

This time, however, the set of η_i are chosen for all ranges for a given depth. This choice results from the conviction that the presence of the low wave velocity surface layer plays a dominant role in determining the observed ground motion phenomenology. The $\bar{\eta}$ computed here will not be the same as the $\bar{\eta}$ used in Section B because the sets over which the averages are taken are different.

Standard deviations of the set of percent deviations from these average values can then be calculated from the usual formula:

$$\sigma = \pm\left[\frac{1}{n} \sum_{i=1}^{n} (\eta_i-\bar{\eta})^2\right]^{1/2}$$

As before, the values of η are not uniformly distributed about zero; positive values cannot be larger than 100. The results in σ will also be skewed. This will not be significant, however, for the intuitive interpretations to be drawn here.

The averages of the percent deviations at constant depths, and their standard deviations, are given in Table 7.3. This presentation of the data allows an evaluation of how the three prediction techniques account for the layer effect. Each entry in the table consists of two terms, in the form $\bar{\eta} \pm \sigma$.

Table 7.3. Averages of Percent Deviations at Constant Depths with Standard Deviations

Event 1					
	AFWL		WES	RDA	
Depth (m)	DI	AI	DI	DI	AI
0.5	-0.94±28	-45±44	-130±155	0.53±53	16±31
1.8	-	-	-175±106	-32±34	-19±107
3.7	-179±63	-170±121	-129±110	-5±27	-210±127
6.1	-	-205±141	-31±21	22±8	-196±87
9.1	-	-	37±3	62±13	-342±285

Event 2					
	AFWL		WES	RDA	
Depth (m)	DI	AI	DI	DI	AI
0.5	6.9±33	15±14	-64±80	31±35	33±16
1.8	-	-	-124±53	-20±37	-35±91
3.7	-177±62	-60±49	-102±17	-10±19	-107±43
6.1	-	-123±85	-190±209	11±28	-99±35

Overall, there is a tendency to overpredict ($\bar{\eta}$ tends to be negative). This is as might be expected in that some of the predictions were made conservatively for gage-ranging. Also, the magnitude of $\bar{\eta}$ generally increases with depth. This implies that the magnitude of the overprediction, at least relative to the magnitude of the measurement, increases with depth. This could arise because of failure to attenuate the predictions properly (or at all) with depth; or it could indicate a difference between the White Sands site and the other sites from which data taken served as the basis for making these predictions by scaling.

D. COMPARISONS OF THE PREDICTIONS

The objective of this section is to compare the predictions of AFWL, WES and RDA on some reasonable basis. The sample sizes (sets) are small, sometimes consisting of only 2 or 3 members, so it is not reasonable to make critical judgements on the basis of individual values of σ. However, the question of how the three techniques fare on the average may be asked. We now form a set of σ for each agency and again compute averages:

$$\bar{\sigma} = \frac{1}{N} \sum_{i=1}^{N} |\sigma_i|$$

where only positive values of the σ_i are used so that $\bar{\sigma}$ must always be positive. The smaller the value of $\bar{\sigma}$, the better the consistency of the prediction; that is, the less scattered are the percent deviation values about their averages. Compare all values of σ from Table 7.3:

	AFWL	WES	RDA
$\bar{\sigma}_{TOTAL}$	64	84	60

On the basis of this comparison, it is probably not possible to distinguish between the AFWL and RDA predictions, but the WES predictions rank somewhat below the others. These results have little to do with conservative overpredicting. A negative bias in $\bar{\eta}$ is suppressed; the comparisons consider only predictive scatter.

Having reduced all of the vertical velocity information to a single number for each agency, we now go back and divide the numbers in two different ways. First, we consider values of $\bar{\sigma}$ calculated separately for the direct-induced (DI) and airblast-induced (AI) motions. Second, we compare values calculated only for the low velocity surface layer with those calculated for the underlying higher velocity layer. The results appear in Table 7.4.

Table 7.4. Values of $\bar{\sigma}$ by Motion Source and by Seismic Layer

By Wave Motion Source			
	AFWL	WES	RDA
Direct-induced	47	84	28
Airblast-induced	76	-	91
By Seismic Layer			
Low velocity layer (0-3 m depth)	30	99	51
High velocity substrate (>3 m depth)	87	72	67

For these cases, the picture is somewhat unclear. It is of course possible that the small size of the statistical sample may be affecting the results unduly. Notice that prediction consistencies in the high velocity substrate show a uniformity among the agencies which is not found in the low velocity surface layer.

E. CONCLUSIONS

The conclusions reached here are based entirely on a study of percent deviations of the vertical components of particle velocity. In these vertical velocity records, the airblast-induced and direct-induced wave components can be distinguished in most cases, at least in the slow layer. Tentative conclusions reached in this study may be stated as follows:

1. All three of the agencies made reasonably successful predictions. This is probably because all three of the techniques used are based essentially on scaling from previous data. Whether or not the prediction techniques are adequate, and how they should be improved, will depend on the needs and resources of the weapons-effects community.

2. Overall, the AFWL and RDA techniques seem to be somewhat more consistent than that of WES, although the statistical comparison suffers from inadequate data.

The conclusions cannot be stated more strongly because there are weaknesses in the analytical procedures brought about by the data reduction technique. Additional analysis, beginning from a re-scanning of the original data traces, will be necessary if a more definitive result is to be obtained.

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