# EFFECTS OF [redacted], LOW-YIELD NUCLEAR WARHEADS ON AIRFIELD RUNWAYS. (U)

MR. LANDON K. DAVIS
U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

Recent changes in the Army's nuclear weapon employment doctrine have placed significant constraints upon the use of such weapons in the tactical theatre. One of the most important of these constraints requires that nuclear strikes against tactical targets be performed in such a manner that undesirable collateral effects, such as casualty-producing fallout, airblast, or thermal effects, be minimized to the greatest possible extent consistent with the mission objectives. The development of an earth-penetrating warhead, together with a missile system capable of delivering such a warhead with extreme accuracy, has been envisioned as a means of meeting these constraints while providing the Army with a new flexibility in the tactical theatre.

A recently-completed study at the Waterways Experiment Station (WES) was designed to evaluate the effectiveness of an earth-penetrating nuclear warhead employed against airfields, which is one of the most important target categories for tactical nuclear attack. The objective of this study was to define damage to airfield runways as a function of warhead yield, burst position, target characteristics, and geological environment. Existing Army manuals stated that damage to runways should extend over a distance equal to 1.5 times the apparent crater diameter. At the onset of this study, it was felt that this estimate was grossly conservative; that effective damage to a runway by a buried nuclear burst might, in fact, be more than twice as extensive.



It was hypothesized that four major zones of damage would be produced in a runway, with the severity of damage decreasing with distance from the burst location. These damage zones are illustrated in Figure 1. The most obviously severe damage would be represented by the nuclear crater itself. In the second zone of damage would be permanent upheaval and disruption of the pavement around the crater. The third zone of damage was expected to consist of isolated areas of pavement displaced by the intense ground shock, or damaged by the impact of pavement debris thrown out during the crater formation. These three zones would all require reconstruction before resuming flight operations, and therefore represent relatively long-term denial of the runway.

The fourth damage zone is the runway area covered by debris thrown from the crater. Since aircraft operations could be resumed after the debris is removed, this zone represents an area of short-term denial. Basic objectives of the study were to determine how far these damage zones would extend from the burst point, and to determine the relative severity of damage that would control the extent of effort and time required to repair these areas for a resumption of aircraft operations.

The research approach for this program was largely experimental in nature. Three phases of tests were conducted in which modeled sections of runway pavements were subjected to the blast and shock effects of scaled buried explosions. To demonstrate first the potential effectiveness of a deeply buried, tactical-yield, nuclear burst against a runway, the initial test phase involved the construction of an 85-metre long, 6-metre wide model section of a cast-in-place, articulated concrete slab runway adjacent to a previously-planned high-explosive (HE) cratering test. This test, called the 12 MS event, was designed to simulate the effects of a very low-yield nuclear burst at a depth of 12 metres. The test was conducted at Fort Polk, Louisiana, in a clay-sand soil similar to soil types occurring in central Europe. The model runway was built to a scale of 1:3.7 so that the 10-ton (9,090-Kg) HE charge would model a 1-kiloton nuclear yield at a burst depth of about 40 metres.

Figure 2 is a photograph of an early stage in the 12 MS event detonation. As can be seen in the photo, the portion of the test runway overlying the crater was lifted by the explosion, with the pavement slabs near the center of the crater being separated and lofted over a hundred metres through the air. The section of runway lying over the outer portion of the cratered area was simply folded back about a hinge point located just outside the edge of the crater. The actual radius of the apparent crater was 18.5 metres. Records obtained from velocity gages located along the length of the runway

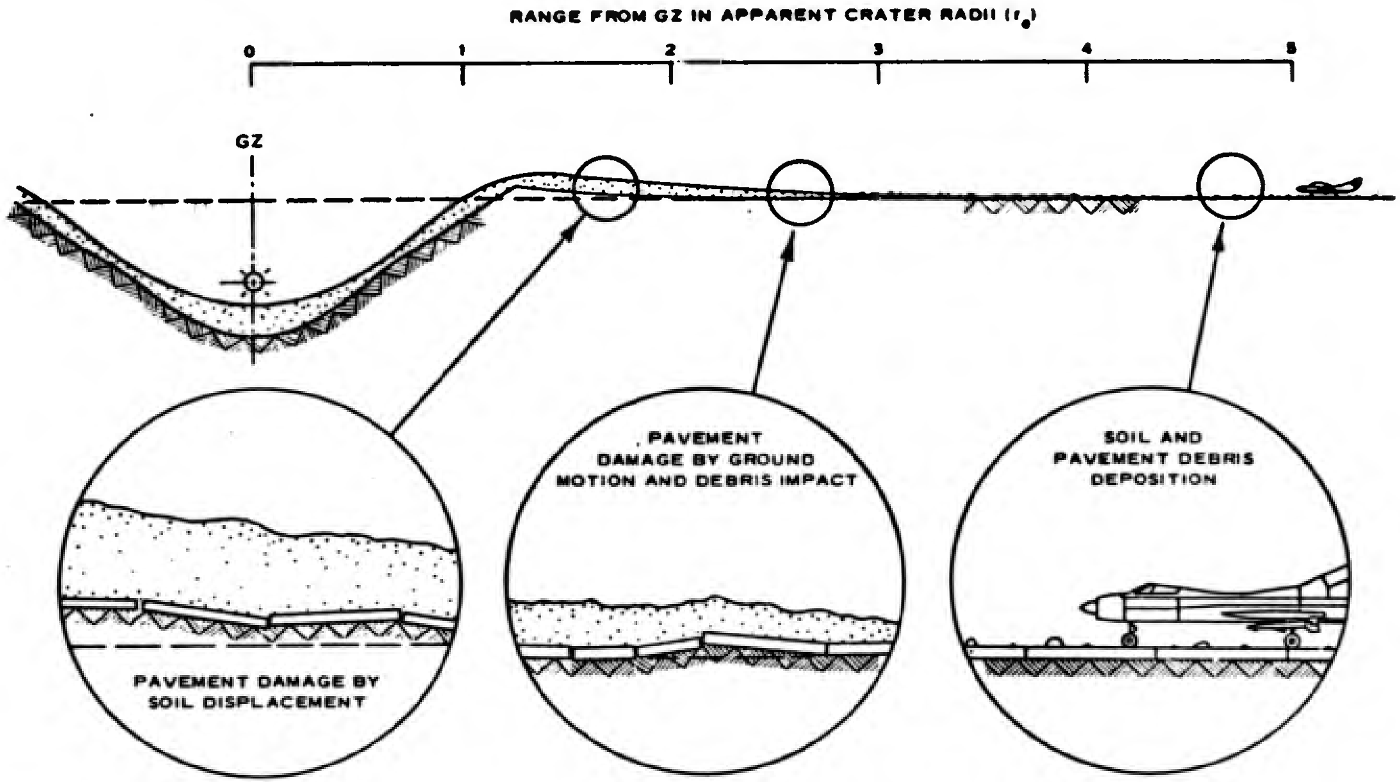



**Figure 1.** Illustration of zones and mechanisms of damage to a concrete slab runway from a buried nuclear explosion. Ranges and occurrences of zones were originally hypothesized for experiment planning only.

Figure 2. Early stage of venting of 12 MS event detonation, showing separation and lofting of runway pavement over crater area and initial upheaval of runway beyond crater edge.

showed that almost the entire length of the pavement was lifted momentarily to heights that decreased logarithmically from over 2 metres at the edge of the crater to a few centimetres at a range of 50 metres from the crater. The permanent vertical displacement of the runway was only slightly less than the peak transient displacement. Figure 3 shows the postshot profile of the runway beyond the edge of the crater (with an exaggeration in the vertical scale for clarity).

Severe permanent uplift of the runway and accompanying distortion of the pavement profile extended to a range of 50 metres from ground zero (GZ), or 2.7 times the apparent crater radius. The velocity gages installed in and below the model runway showed that the rigid pavement moved independently of the underyling soil, particularly in the horizontal direction. Relative peak displacements of the pavement and the soil base are shown in Figure 4. No evidence was found of damage to the runway from the ground shock.

Beyond the uplifted region, the pavement did sustain moderate to severe damage at isolated points from the impact of whole or large pieces of pavement debris thrown from the crater area. Figure 5(a) shows the location of crack damage in a plan view of the runway strip, and Figure 5(b) shows the areas of the pavement judged to be unusable for aircraft operations due to such debris impact damage.

The second phase of testing was designed to relate the extent of runway damage to runway pavement design and to the nuclear warhead burst depth. Four tests were conducted at Camp Shelby, Mississippi, in which 450-Kg HE charges were detonated at depths ranging from 0 to 7 metres. Four 1/12-scale model runway sections were constructed for each test, representing articulated concrete slab pavements, continuously reinforced concrete (CRC) pavements, asphalt pavements, and an expedient stabilized soil runway. Because of the small scale of these tests, it was felt that the results were not scalable to realistic weapon yields and full-scale runways. However, measurements obtained from the 1/12-scale tests provided a valuable indication of the relative changes in damage levels as a function of the weapon burst position and the pavement design.

The final experimental phase was a second large-scale test at Fort Polk, Louisiana, in which runway sections were again built to the 1:3.7 scale and subjected to the effects of a 10-ton HE detonation. In this test, called the 3 MS event, the charge was buried 3 metres deep, and four pavement designs were tested as in the 1/12-scale tests.

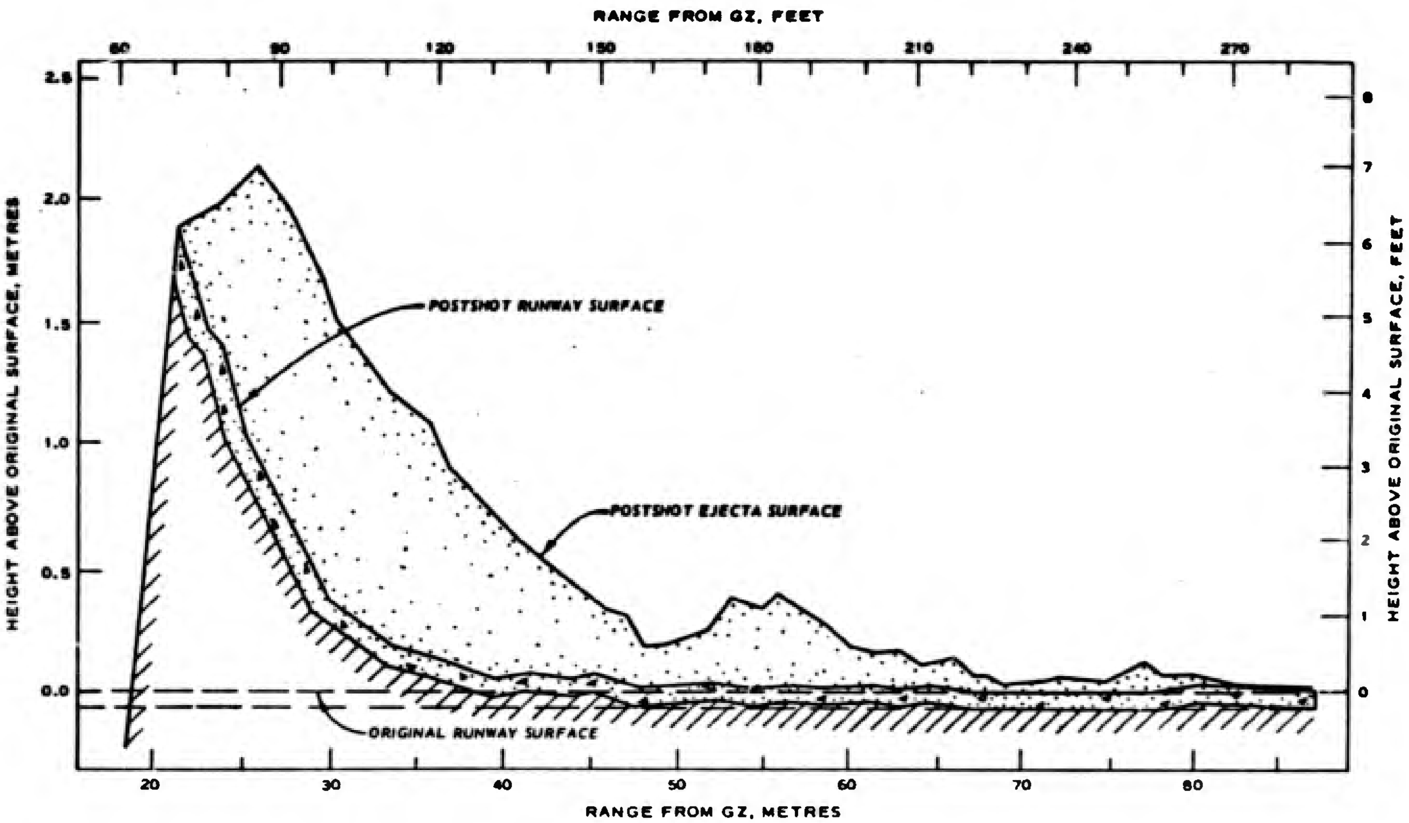



Figure 3. Profile of postshot runway from 12 MS event showing permanent vertical displacement and ejecta coverage depth. Vertical scale is exaggerated for clarity. Profile shown is average of centerline, right edge, and left edge profiles of runway.

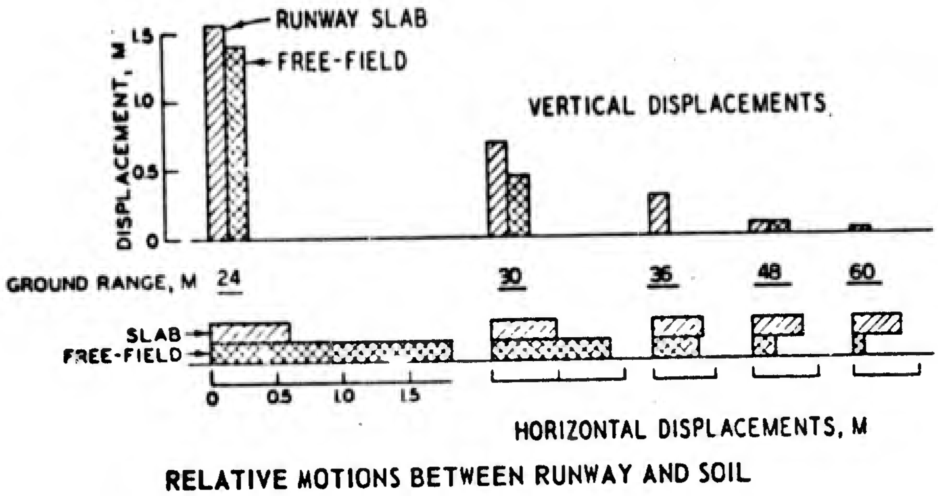



Figure 4. Comparison of relative peak transient displacements of runway versus underlying soil for 12 MS event.

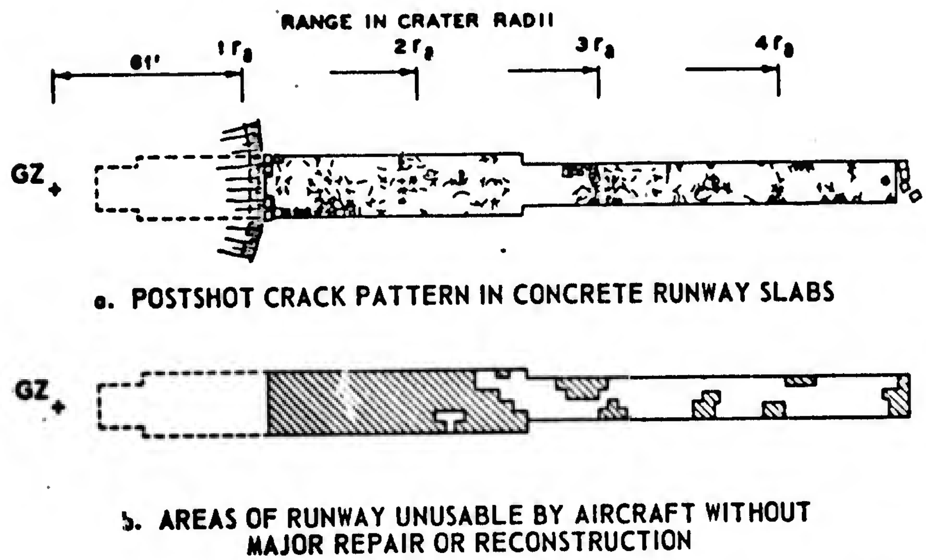



Figure 5. Distribution of crack damage in postshot runway surface, 12 MS event. Damage beyond 2.7 $r_a$ was due to impact of debris thrown from crater.

As predicted from the results of the 1/12-scale tests, damage to the runways from the 3 MS detonation was much less extensive than produced by the deeper 12 MS detonation. On the articulated concrete slab runway, upheaval damage near the crater extended only 16 metres beyond the crater edge, compared to 31.5 metres beyond the 12 MS crater. Damage to the CRC pavement was slightly more extensive. As expected, the asphalt and stabilized soil pavements were disrupted over significantly greater distances than were the concrete pavements.

Because of the shallow burst depth for the 3 MS event, the intense shock from the detonation shattered much more of the pavement overlying the crater area than occurred for the deeper 12 MS event. The pavement debris was also ejected at much higher velocities, so that the wide distribution of debris impact points around the crater resulted in a low areal density of debris impacts. Consequently, there was little impact damage to the pavements.

Figure 6 is a graph relating the radial extent of upheaval damage in the various pavement designs to the explosion depth of burst. All dimensions are normalized by dividing the damage radii, measured from GZ, by the 1/3.4th power of the explosive charge weight. As mentioned previously, the 1/12-scale data were not intended to scale, but to reveal the relative differences in damage radii for different pavement types and depths of burst. In this respect, the small-scale test data served to better define the slopes of the damage curves for the larger scale test data.

In applying these HE test results to predictions for nuclear bursts, an additional problem stems from the fact that HE/nuclear explosive (NE) equivalence factors change drastically as the burst point approaches the ground surface. For scaled burst depths greater than about 15 metres/$KT^{1/3.4}$, an HE detonation produces blast effects equivalent to an NE detonation of roughly twice the yield, i.e., a 20-ton HE detonation would simulate a 40-ton NE detonation. For shallower bursts, the early venting of the explosion results in a loss of radiant energy that would otherwise contribute to cratering and ground shock effects.

An examination of existing NE and large-scale HE test data indicates that the upheaval of the ground surface around a crater is a constant function of the apparent crater size for a given scaled burst depth in a given type of soil. Since the runway damage radii reported here result from such upheaval, an HE/NE damage equivalency was empirically developed from a comparison of HE and NE crater radii and surface displacements (i.e., upheaval) from detonations at

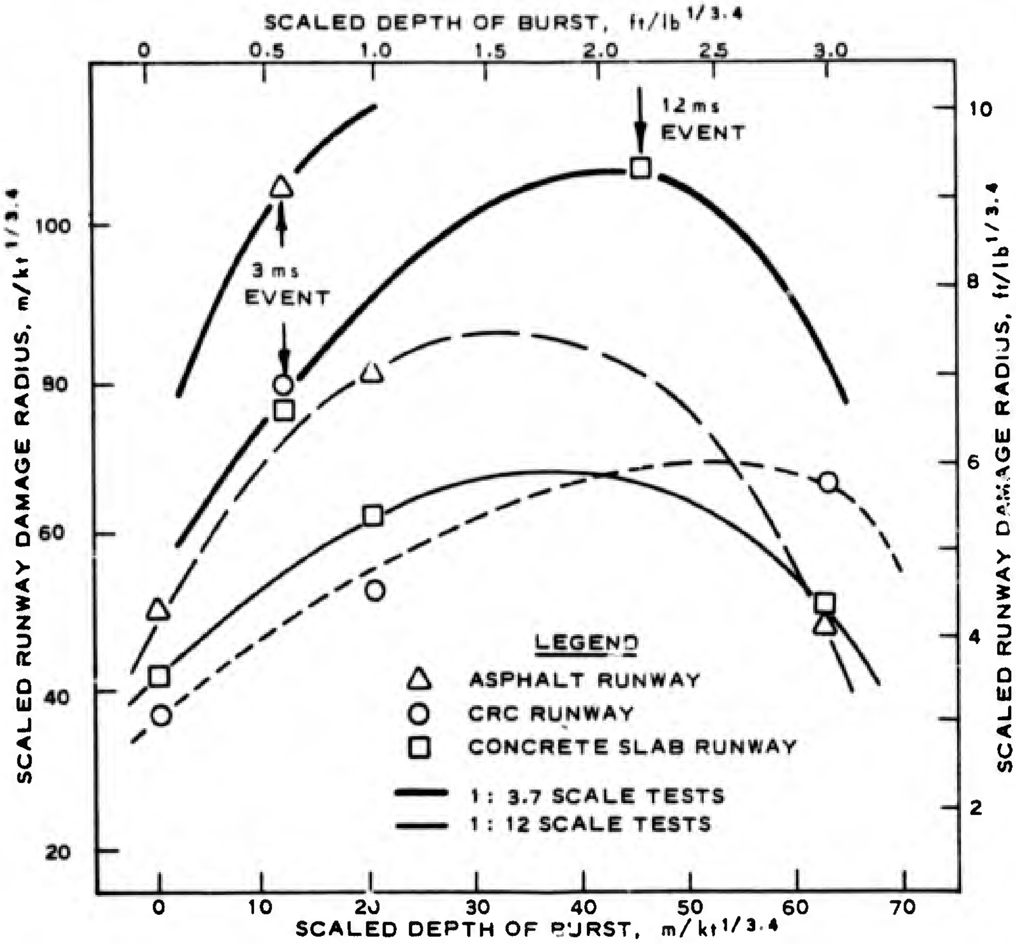



Figure 6. Scaled runway damage radius versus scaled depth of burst, as measured in model runways subjected to high-explosive tests. Radii shown are for pavement damage from upheaval only.

various shallow depths in various geologies.

Using these empirically-derived HE/NE equivalence factors, a final set of damage curves was developed to predict runway damage radii as a function of nuclear yield and burst depth in a sandy-clay geology. Figure 7 shows the scaled damage radii for the concrete slab runway, both in terms of scaled radius from GZ and in multiples of apparent crater radii. The damage radius for a nuclear surface burst is roughly twice the crater radius, compared to almost three times the crater radius for a deep burst. The actual radius of damage for a deeply buried burst is 2.2 times that for a surface burst. This implies that a nuclear surface burst requires 15 times the yield of a deeply buried nuclear burst to produce an equivalent amount of runway damage.

Again, the runway damage discussed here is that resulting solely from upheaval of the ground surface around the crater. A deeply buried burst will also produce additional damage beyond the upheaval region by the ejection and impact of pavement debris. There are not sufficient quantitative data available to state definitely the denial value of such "bonus" damage. However, the impact of a 5- to 20-ton slab of concrete falling on a concrete pavement from a height of a hundred metres or more should produce sufficient damage to prevent an aircraft from taking off across the impact area.

Figure 8 shows the damage areas in a concrete runway from a nominal 1-kiloton nuclear burst. Figure 8(a) shows the damage area from a buried burst, as predicted from Army manuals prior to this study. Figure 8(b) shows the revised predictions for a deeply buried burst based on the results of the study, and Figure 8(c) shows similar predictions of damage for a 1-kiloton surface burst.

In conclusion, the results of this research program have shown that tactical earth-penetrating warheads are, by conservative estimate, almost twice as effective in runway area denial as was previously assumed. If debris impact damage is also considered, the damaged runway length will be three times as great as previous data indicated, and the total airfield damage area, including sod strips adjacent to the runway, will be nine times as great. From a weapons effectiveness standpoint, tactical earth-penetrating warheads appear to offer the Army a viable means of selective destruction or denial of enemy airfields, while greatly reducing the collateral damage associated with the present air-burst warhead system.

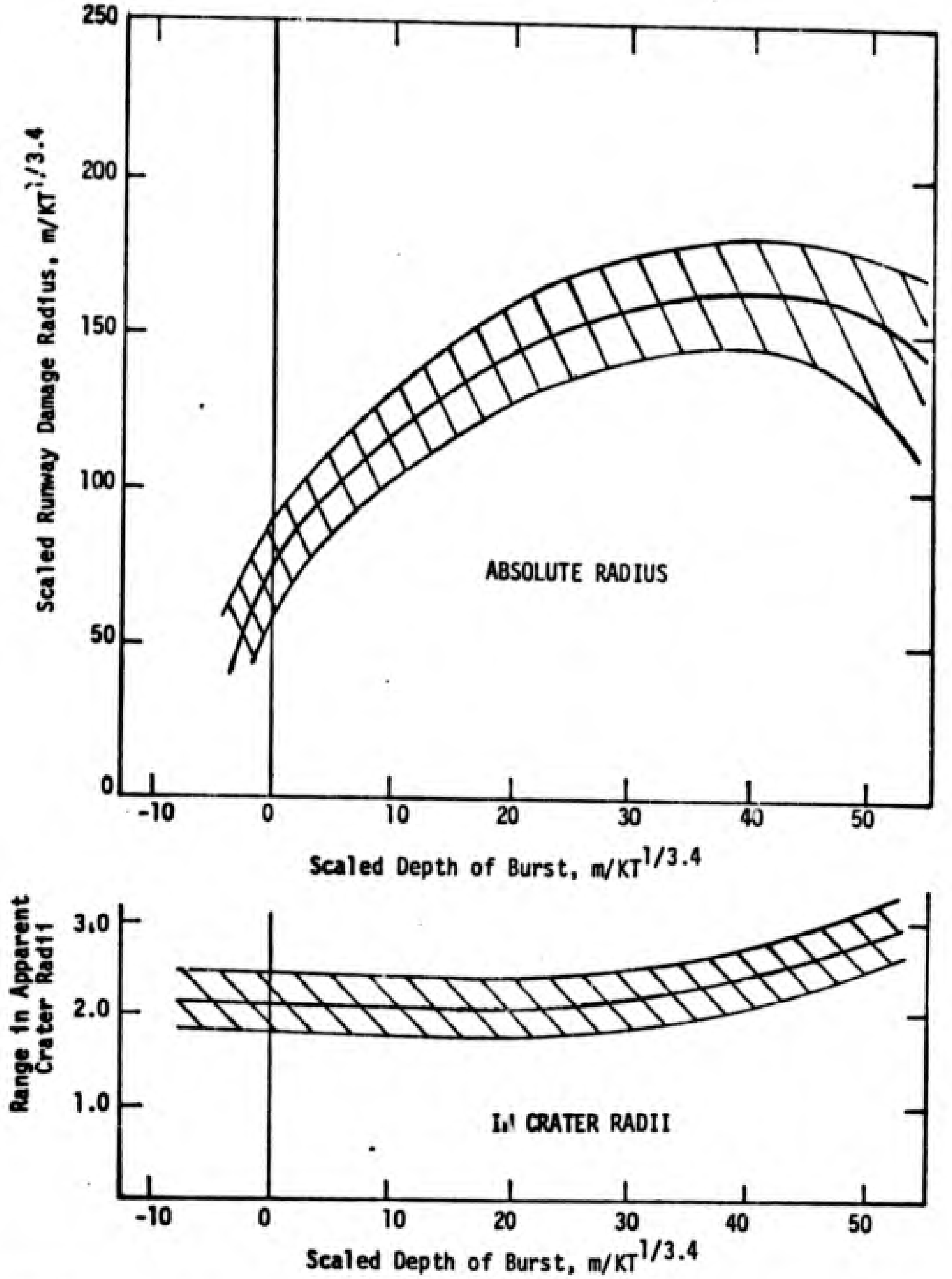
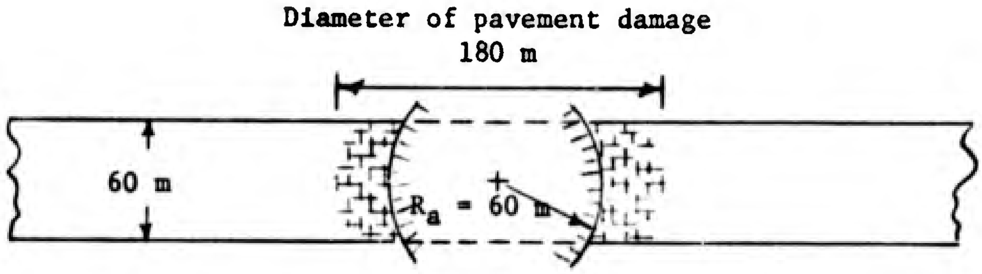
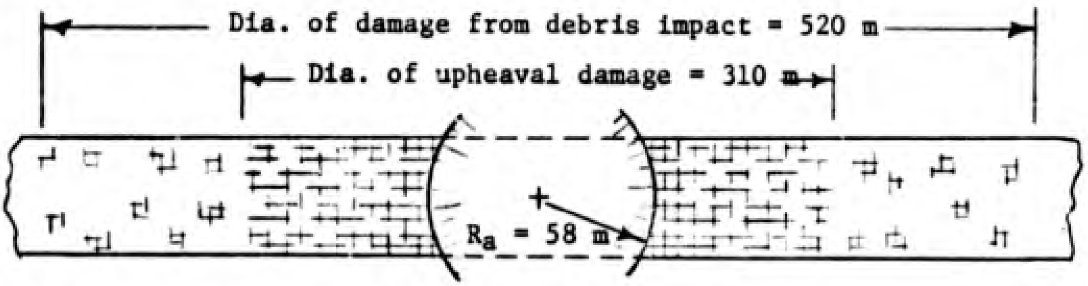


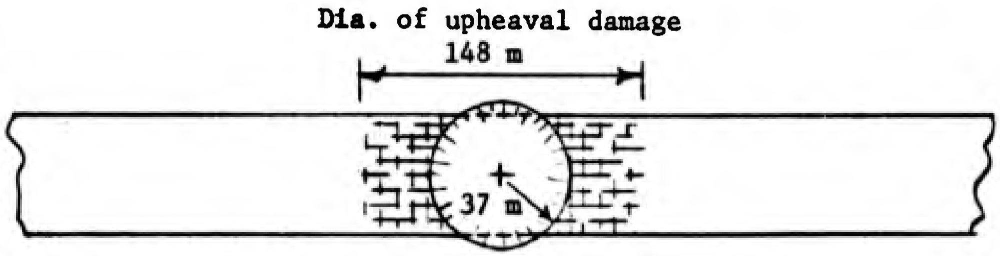

**Figure 7.** Scaled damage radius in a concrete slab runway pavement for tactical-yield nuclear detonations in moist sandy-clay geologies.




a. Previous prediction for 1-KT burst at 40 m depth.




b. Revised prediction for 1-KT burst at 40-m depth.




c. Revised prediction for 1-KT surface burst.

Figure 8. Predicted diameters of damage to concrete slab runway pavements from 1-KT nuclear detonations. $R_a$ is apparent crater radius.