1990_08

Mitigation Diagnostics: The Need for Understanding Both HVAC and Geologic Effects in Schools

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Experience in the remediation of schools and other large buildings has shown the importance of the effects of both the location of geologic sources and HVAC-induced distribution of indoor radon. In general, elevated radon in areas of schools with evenly distributed HVAC pressures are correlated with maximum soil radon emanations. However, strong or unequal HVAC effects can redistribute indoor radon to areas away from the direct source. Effective remediation required a complete understanding of both contributions.

In some schools, highest indoor radon levels were located near large return ducts and were attributed to proximity to negative HVAC pressure. Successful sub-slab depressurization systems were installed, however, in rooms with lower indoor but greatest sub-slab radon levels, closest to the source. This shows the inadequacy of using indoor radon levels alone as a basis for remediation.

Wings of two other schools with radon problems have equivalent window fan coil units in rooms of equal size and no central HVAC system. Highest indoor radon levels correlated well with highest sub-slab radon levels due to the equivalent effects of the window units.

Diagnostic tests in other schools have revealed: blockwall radon transport to upper floors; high blockwall radon adjacent to sub-slab sources; and elevated indoor radon over crawlspace being drawn upward by HVAC-induced negative pressure, determined from indoor to outdoor micromanometer measurements.

In the past three years Radon Control Professionals, Inc. has conducted radon soil analyses at approximately 20 school and numerous other construction sites in the Washington, DC area (Northern Virginia and Montgomery County, MD) to predict indoor radon potentials. Previous soil gas surveys showed correlations with indoor radon in existing buildings (Hall, 1988) and revealed that radon sources occur along narrow linear trends within footprint confines of a single building, correlative with geologic structures in metamorphic and sedimentary rock terrains (Hall, 1989). In addition, we have performed radon remedial diagnostics and remediation in 20-30 schools and other large buildings.

Our experience has shown the importance of the effects of both the location of geologic sources and HVAC-induced distribution of indoor radon. In general, elevated radon in areas of schools with evenly distributed HVAC pressures are correlated with maximum soil radon emanations. However, strong or unequal HVAC effects can redistribute indoor radon to areas away from the direct source. Effective remediation required a complete understanding of both contributions.

In some schools with central HVAC systems, highest indoor radon levels were located near large return ducts. However, highest sub-slab radon measurements were often located in neighboring rooms with lower indoor radon levels indicating that the negative pressure created by the return ducts had a more important contribution to elevated indoor radon than source strength (Figures 1, 2, and 3; In all figures, although some alpha track measurements were available, indoor radon levels are two-day charcoal tests performed during the same winter season for comparison). Successful sub-slab depressurization systems were installed in rooms with lower indoor but greatest sub-slab radon levels, closest to the source. This shows the inadequacy of using indoor radon levels alone as a basis for remediation.

The school shown in Figure 3 has a plenum ceiling with openings for return air. The room with 3.2 pCi/l has no windows or return openings in the plenum ceiling. Differential pressure measurements between this room with the door closed and the hallway showed no significant difference until a nearby outside door was opened and hallway air rushed outside (Table 1). We suggested sub-slab depressurization for this room because it had the potential for higher radon levels if openings were added in the return plenum ceiling or doors were opened, because both would depressurize the room.

Wings of two other schools with radon problems have equivalent window fan coil units in rooms of equal size and no central HVAC system. Highest indoor radon levels correlated well with highest sub-slab radon levels due to the equivalent effects of the window units. (Figures 4 and 5). This was verified by an outside corner room in Francis Scott Key High School (Figure 4) with 1.0 pCi/l indoor radon and 132 pCi/l sub-slab radon, the lowest source strength found. Sub-slab/indoor radon ratios were approximately 100/1. The rooms with elevated radon are aligned along a N60°W trend, correlative with local shear fractures (Hall, 1989). In Cannon Road Elementary School (Figure 5), rooms with elevated radon levels are aligned along a N30°E trend, correlative with local rock layers or foliation (Hall, 1989). Thus in schools with equivalent HVAC effects, geologic source appears to dictate indoor radon concentrations.

Martin Luther King Junior High School (Figure 6) revealed indoor radon migration through block walls from the first floor to the second floor. Rooms near the center of the school and in the southeast corner had both first and second floor radon levels equivalent to adjacent block wall radon levels, showing that second floor radon problems were caused by vertical migration through block walls. Sub-slab depressurization with accurately placed block wall penetrations remediated the school.

Two schools (Figures 7 and 8) showed approximately equivalent block wall/sub-slab radon concentrations revealing the need to assess blockwall radon levels to appropriately mitigate blockwalls where needed.

In one school radon problems existed over one end of a room (F104) underlain by the un-vented end of a crawlspace (Figure 9). Table 2 shows the results of indoor/outdoor Δ P measurements with a micromanometer. A Tygon tube was run from the high pressure port of the micromanometer to outside a window, sealed shut with tape, while the low pressure port was open to first the room and then the crawlspace. An aquarium stone was attached to the high pressure tube outside to minimize wind effects. The differential pressures were then measured in both the room and the crawlspace by turning the central HVAC system on with the exhaust fan off and then with the exhaust fan on. Results reported in Table 2 show that the HVAC system created a negative pressure in the room resulting in radon levels nearly as high as a two-day average within 60 seconds. The exhaust fan, blowing from the room into the crawlspace, diminished this effect. In the crawlspace, the HVAC system created an equal negative pressure with the exhaust off but higher radon levels. However, the exhaust fan created a positive pressure in the crawlspace greatly diminishing the radon levels. Therefore remediation was achieved by adding another crawlspace vent below the problem room and running an exhaust line from a roof-mounted fan into the crawlspace, as shown in Figure 9, to pressurize the crawlspace.

The major conclusion is that all aspects of both the HVAC system and the sub-slab geology should be analyzed for each school or other large building individually to achieve optimum remediation.

REFERENCES:

Hall (1988) Proceedings of EPA/USGS Soil Gas Meeting, September 14-16, 1988, Washington, DC.

Hall (1989) Proceedings of the Annual Meeting of the American Association of Radon Scientists and Technologists, October 15-17, 1989, Ellicott City, MD.

LIST OF FIGURES

* In all Figures, indoor radon levels are in the center of each room. Both sub-slab radon levels, adjacent to circles, and blockwall radon levels, adjacent to

TABLE 1. Ridgeview Junior High School - ΔP Effect From Open Doors

TABLE 2. White Oak Middle School - ΔP and Radon Dependency on HVAC and Exhaust Fan

SPRINGBROOK HIGH SCHOOL

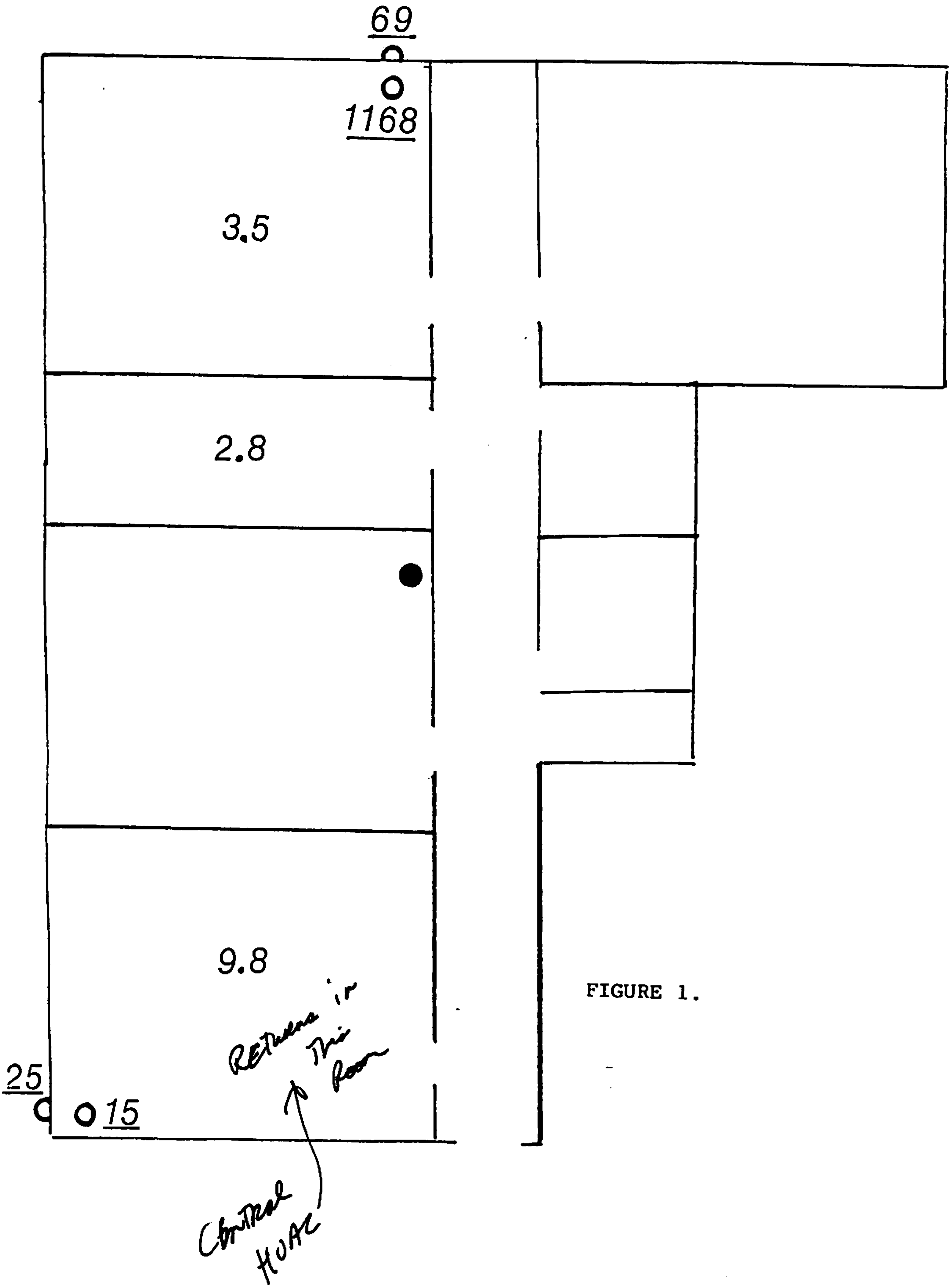


FIGURE 1.

WHITTER WOODS ELEMENTARY SCHOOL

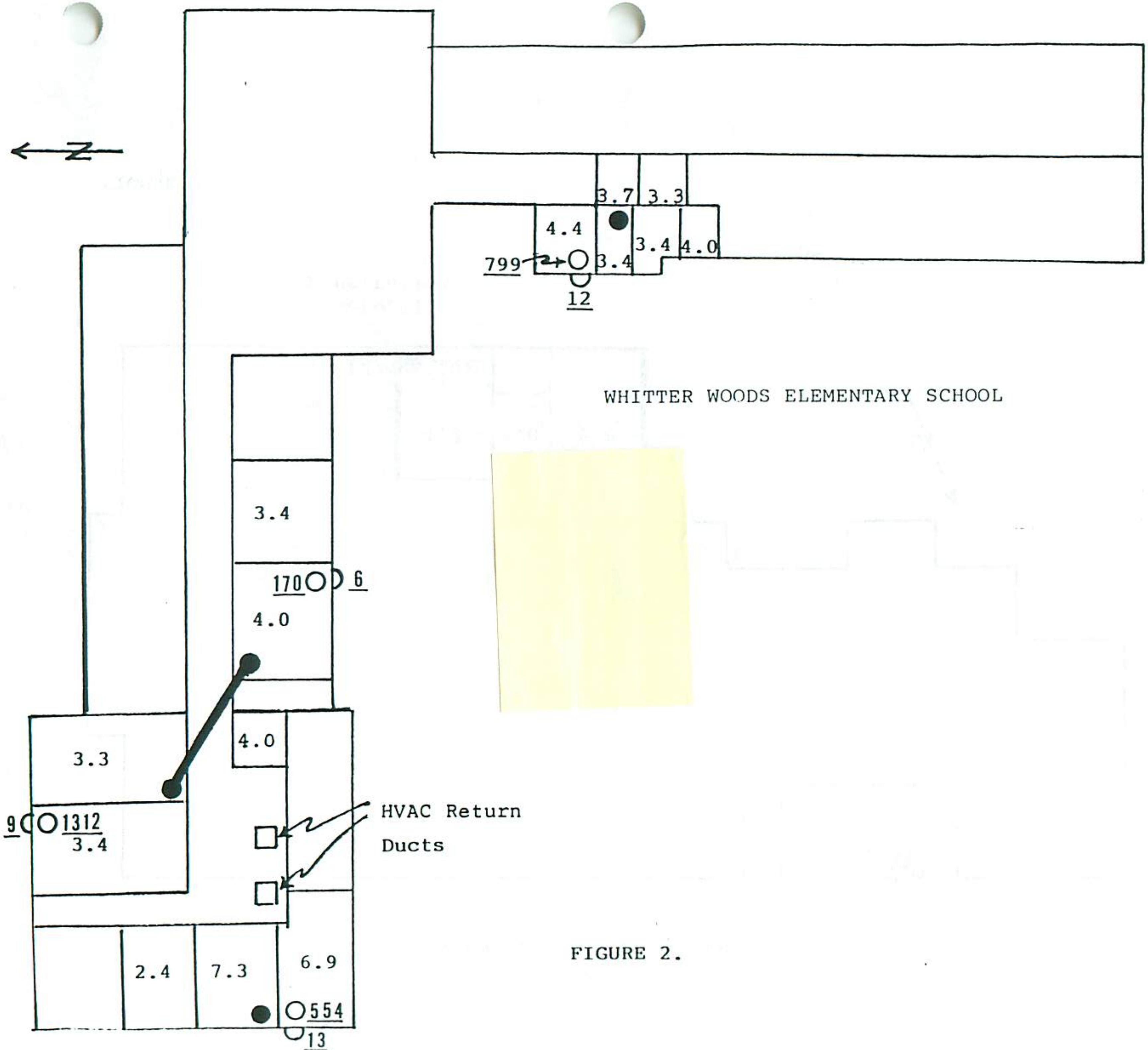


FIGURE 2.

RIDGEVIEW JUNIOR HIGH SCHOOL

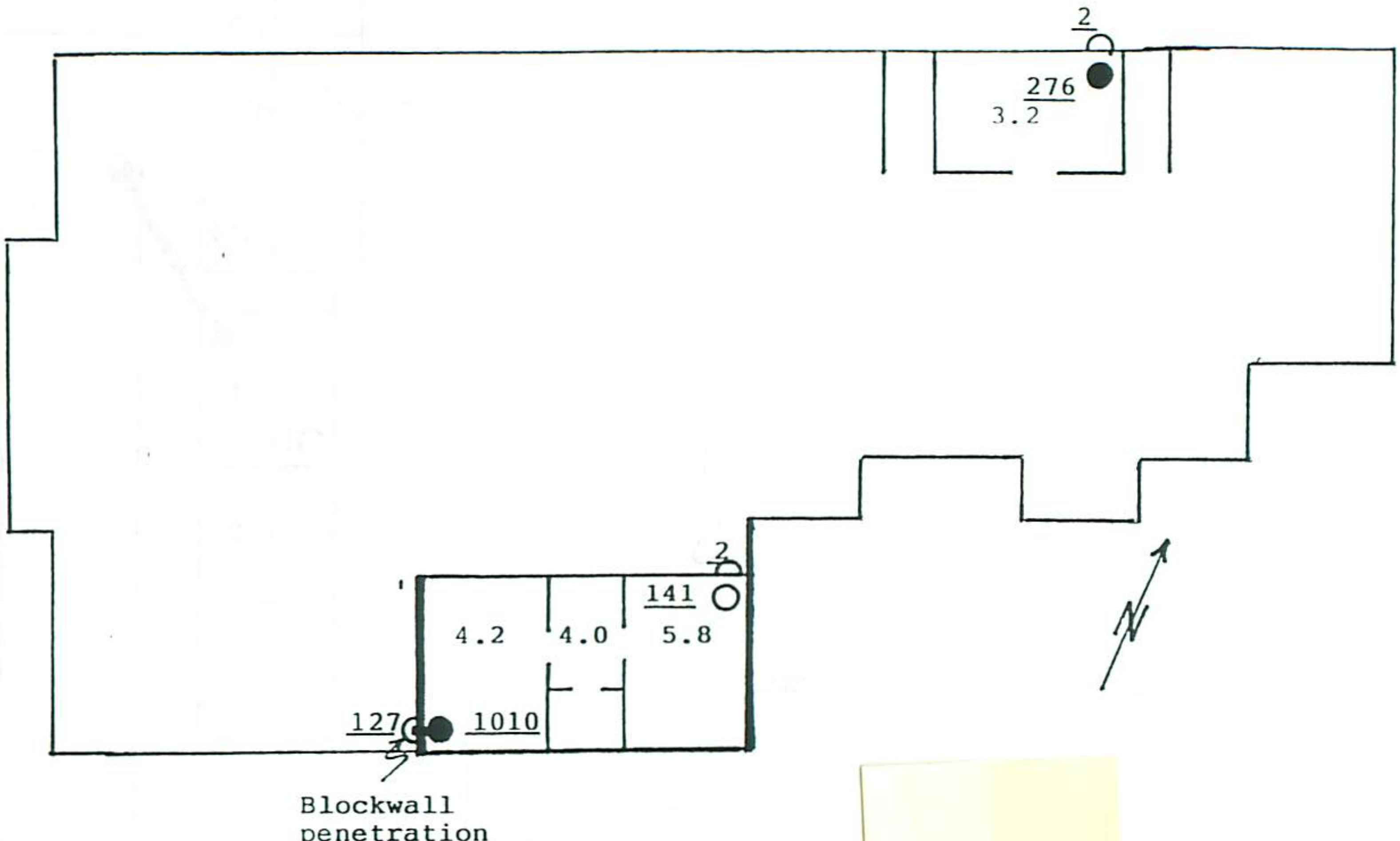
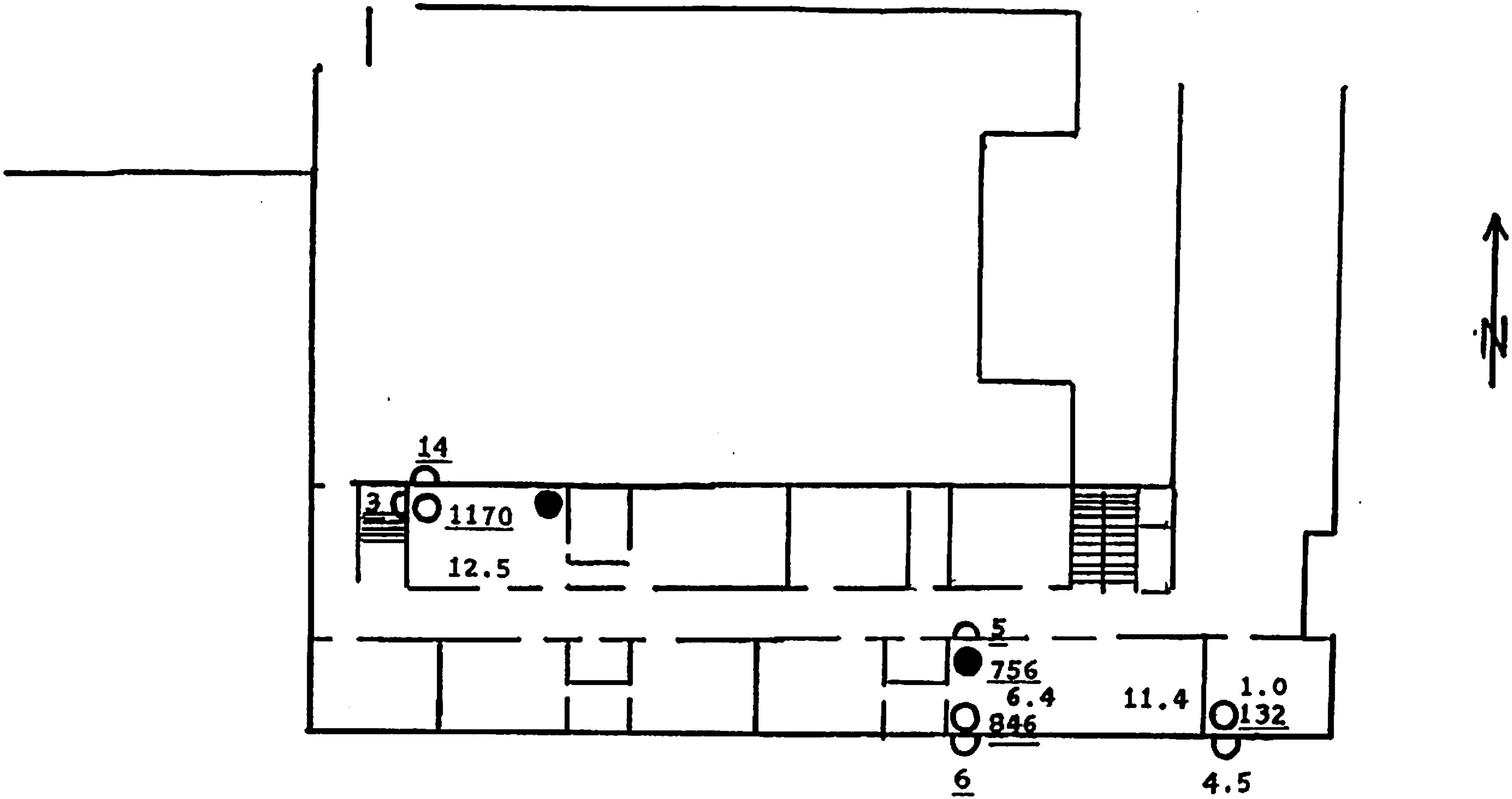


FIGURE 3.

RIDGEVIEW JUNIOR HIGH SCHOOL

ROOM 119:	TIME, SEC.	INDOOR/HALLWAY, ΔP, INCHES H_2O COLUMN
HVAC ON	30	-.001
	60	-.001
	90	-.001
	120	-.001
ADJACENT OUTSIDE	150	+.017
DOOR OPENED-HALLWAY	180	+.020
AIR RUSHED OUTSIDE	210	+.020

TABLE 1.



FRANCIS SCOTT KEY HIGH SCHOOL

FIGURE 4.

100/1 Relationship Soil To Room pCi/l

CANNON ROAD ELEMENTARY SCHOOL

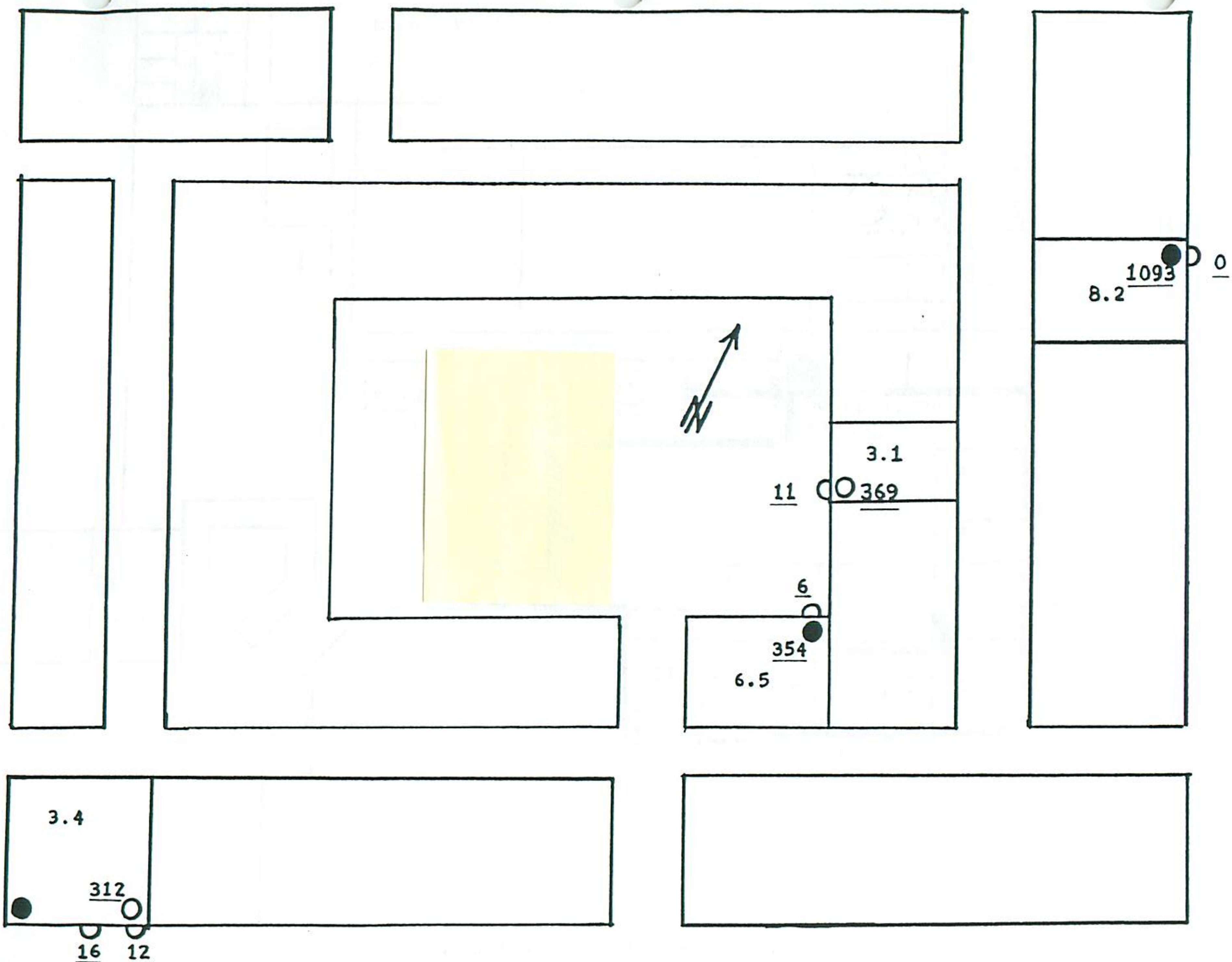


FIGURE 5.

MARTIN LUTHER KING JUNIOR HIGH

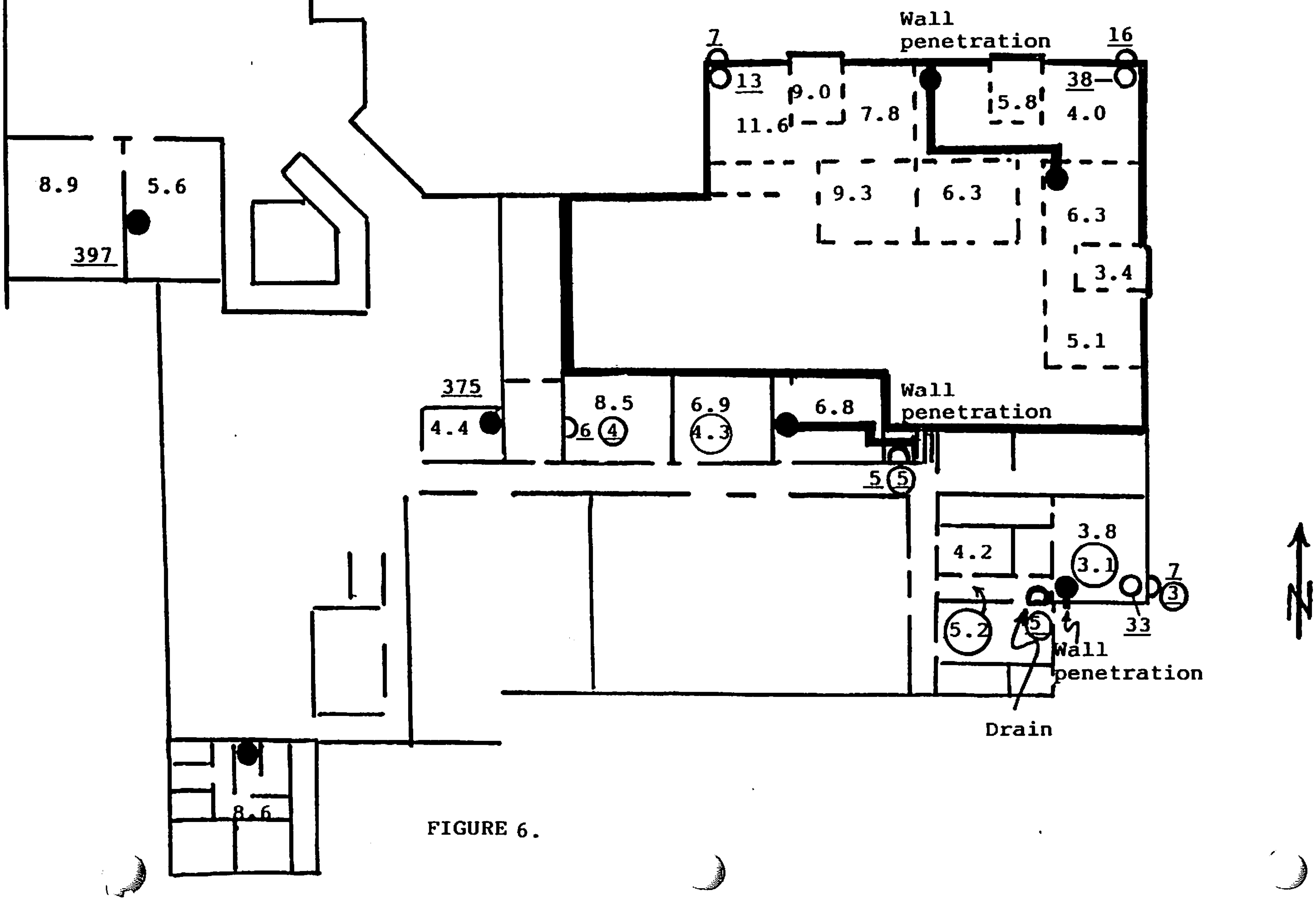


FIGURE 6.

SPRINGBROOK HIGH SCHOOL

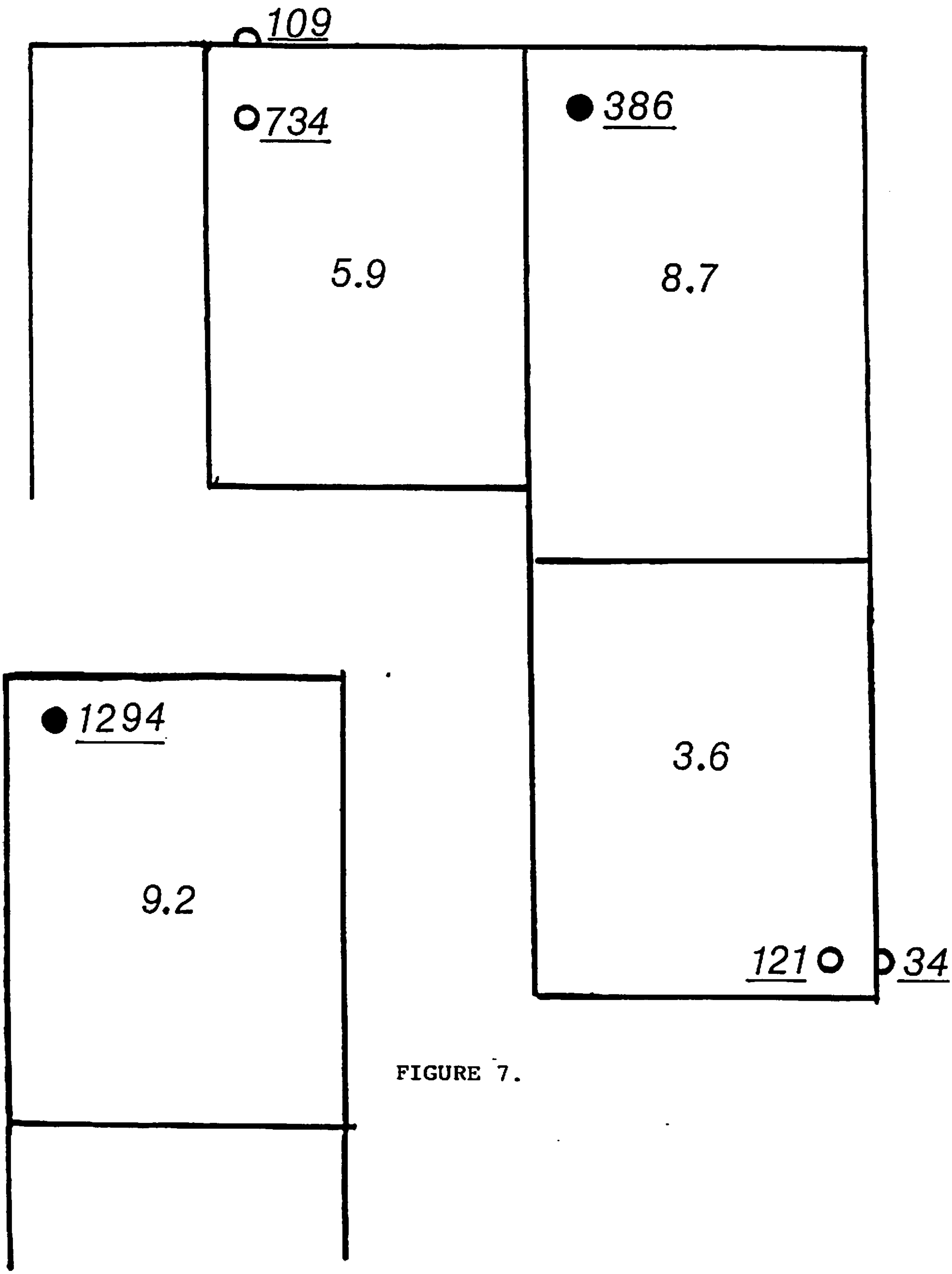


FIGURE 7.

RIDGEVIEW JUNIOR HIGH SCHOOL

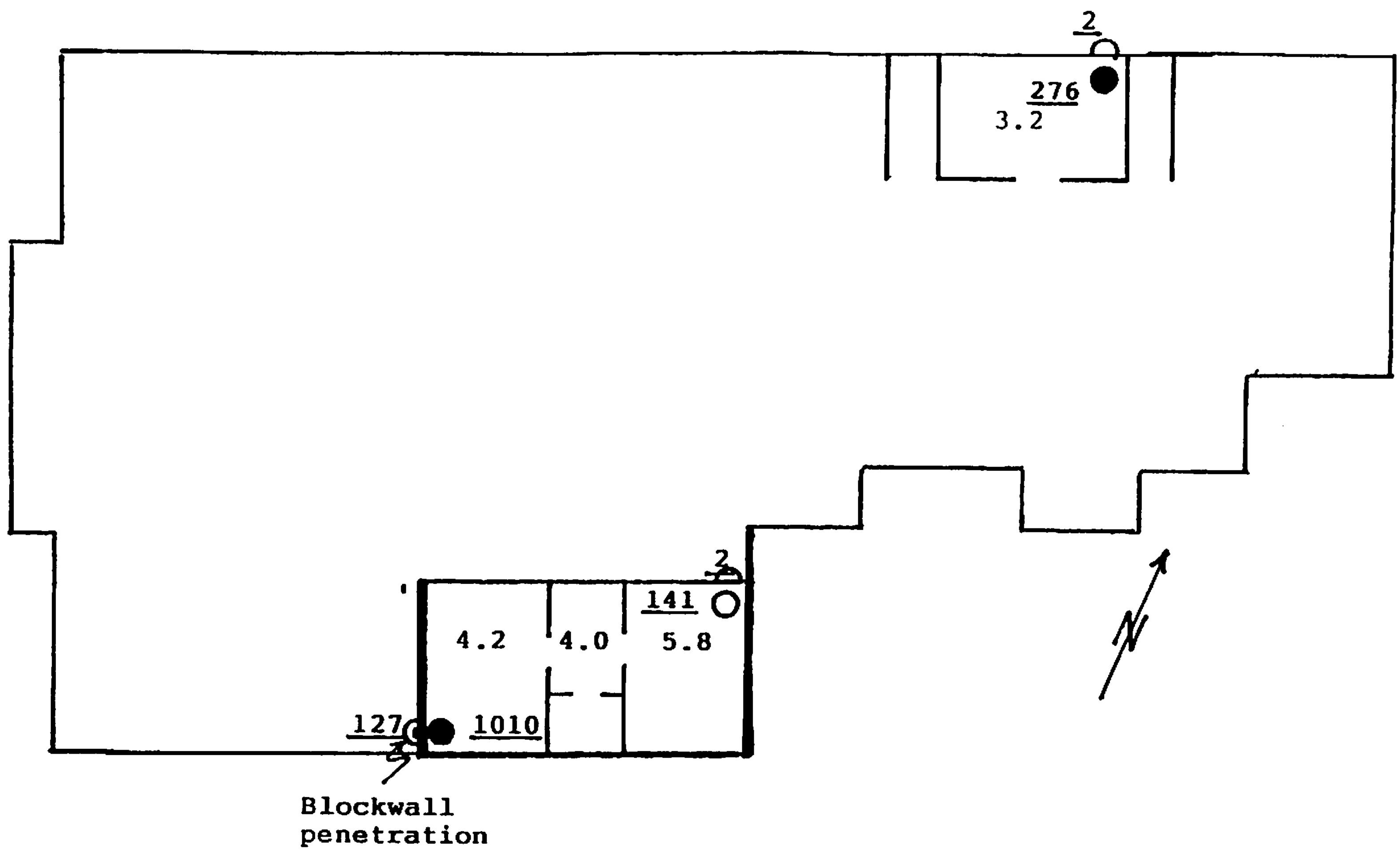


FIGURE 8.

WHITE OAK MIDDLE SCHOOL

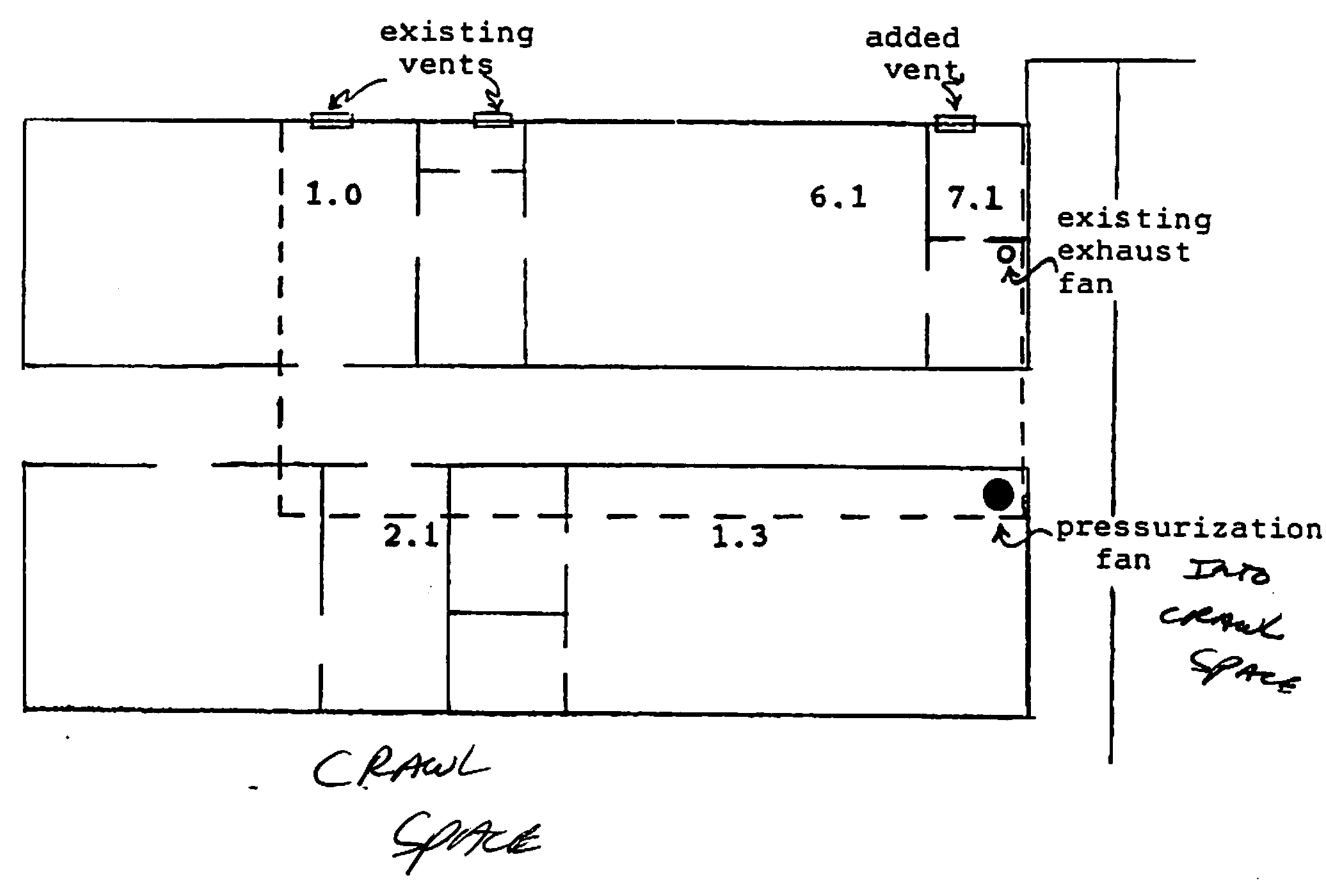


FIGURE 9.

WHITE OAK MIDDLE SCHOOL

	TIME, SEC.	INDOOR/OUTDOOR, ΔP, INCHES H_2O COLUMN	Rn, pCi/l
ROOM F104:			
HVAC ON, EXHAUST FAN OFF	15	-.005	
	30	-.008	
	60	-.010	4.5
HVAC ON, EXHAUST ON	15	0	
	30	0	
	60	-.002	
	120	-.005	<0.1
CRAWLSPACE:			
HVAC ON, EXHAUST OFF	15	-.005	
	30	-.008	
	60	-.010	13.0
HVAC ON, EXHAUST ON	15	+.050	1.4
	30	+.100	<0.1

TABLE 2.