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MITIGATION DIAGNOSTICS: THE NEED FOR UNDERSTANDING BOTH HVAC AND GEOLOGIC EFFECTS IN SCHOOLS

by: Stephen T. Hall
Radon Control Professionals, Inc.
Reston, Virginia 22094

ABSTRACT

Experience in the remediation of schools has shown that in some, highest indoor radon levels were located near large central HVAC return ducts and were attributed to the predominance of and the 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 other schools with radon problems have window heating 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 and the predominance of geology.

Diagnostic tests in other schools have revealed: blockwall radon transport to upper floors; elevated blockwall radon adjacent to sub-slab sources; and elevated indoor radon above a crawlspace caused by HVAC-induced negative pressure.

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In the past three years the author 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 (1) 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 (2). In addition, Radon Control Professionals has 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, shown in the center of each room, are two-day charcoal tests performed during the same winter season for comparison. Both sub-slab radon levels, adjacent to circles, and blockwall radon levels, adjacent to semi-circles, are underlined.) 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.

SPRINGBROOK HIGH SCHOOL

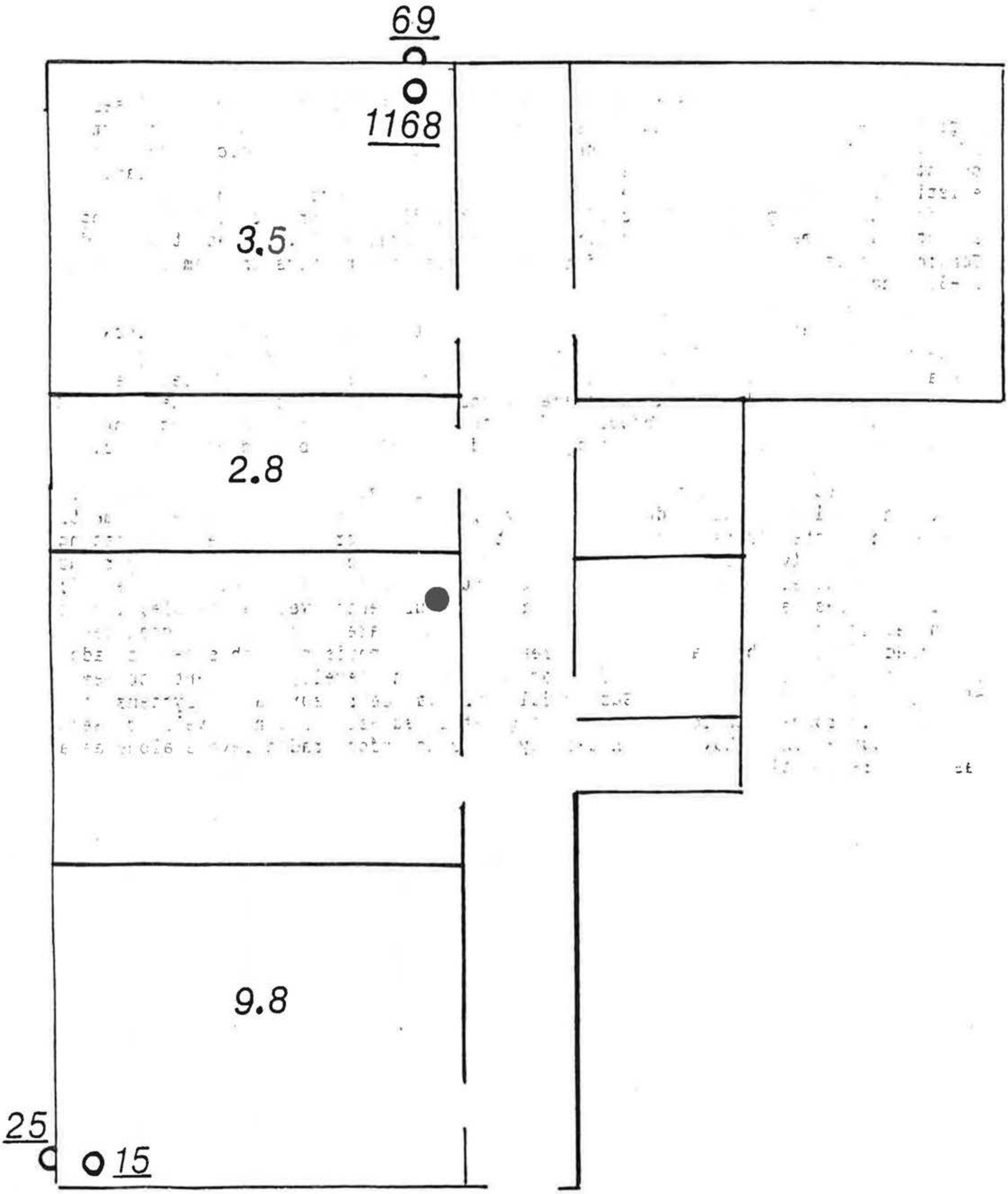


FIGURE 1. Springbrook High School - Indoor radon levels not correlated with sub-slab radon levels due to HVAC effects predominant over geologic source effects. In all Figures, indoor radon levels are in the center of each room. Both sub-slab radon levels, adjacent to circles, and blockwall radon levels, adjacent to semi-circles, are underlined.

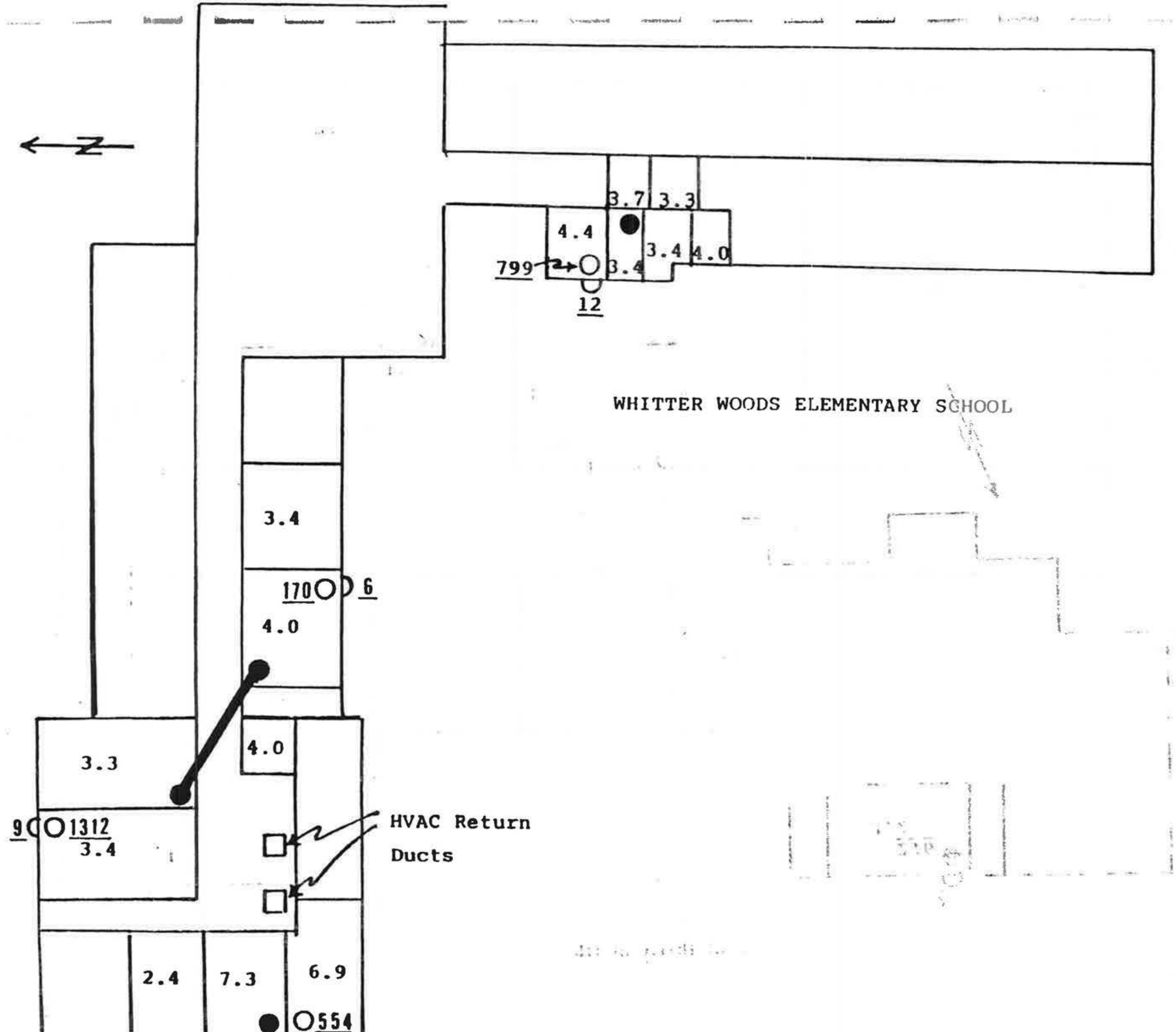


FIGURE 2. Whitter Woods Elementary School - Indoor radon levels not correlated with sub-slab radon levels due to HVAC effects predominant over geologic source effects

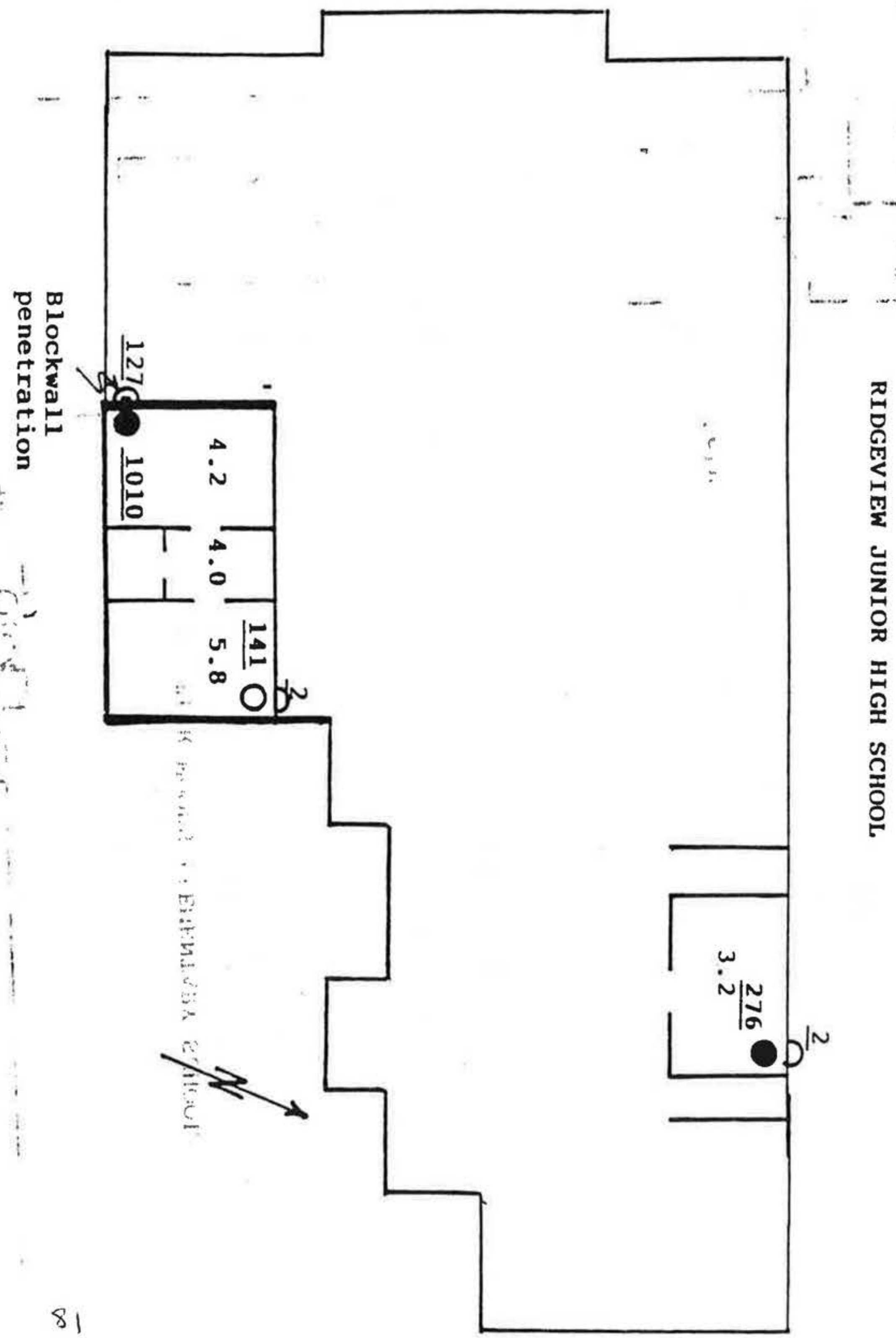


FIGURE 3. Ridgeview Junior High School - Indoor radon levels not correlated with sub-slab radon levels due to HVAC effects predominant over geologic source effects

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.

TABLE 1. RIDGEVIEW JUNIOR HIGH SCHOOL - ΔP EFFECT FROM OPEN DOORS

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

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 (2). 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 (2). Thus in schools with equivalent HVAC effects, geologic source appears to dictate indoor radon concentrations.

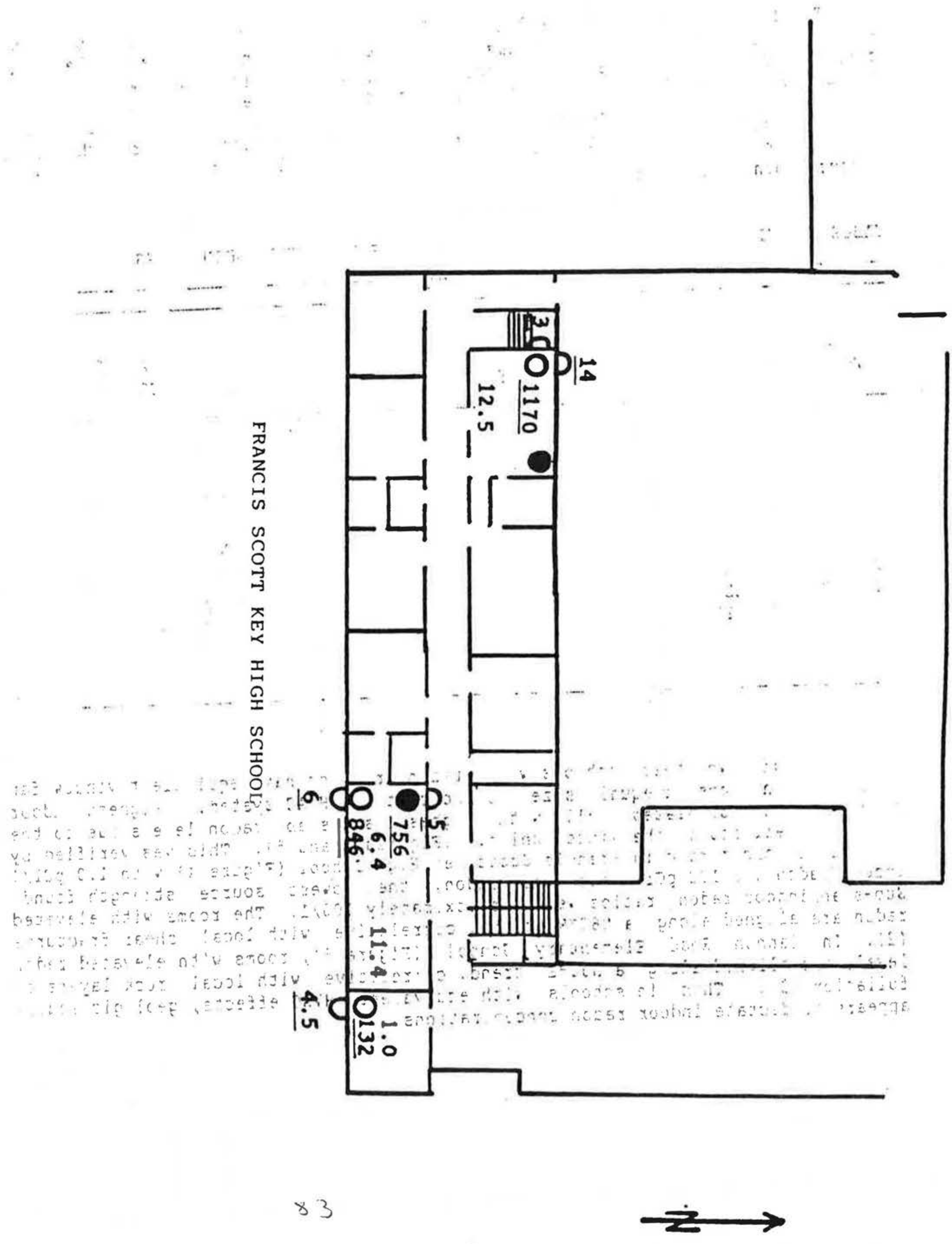


FIGURE 4. Francis Scott Key High School - Indoor radon levels proportional to sub-slab radon levels due to equivalent HVAC effects and predominant geologic control

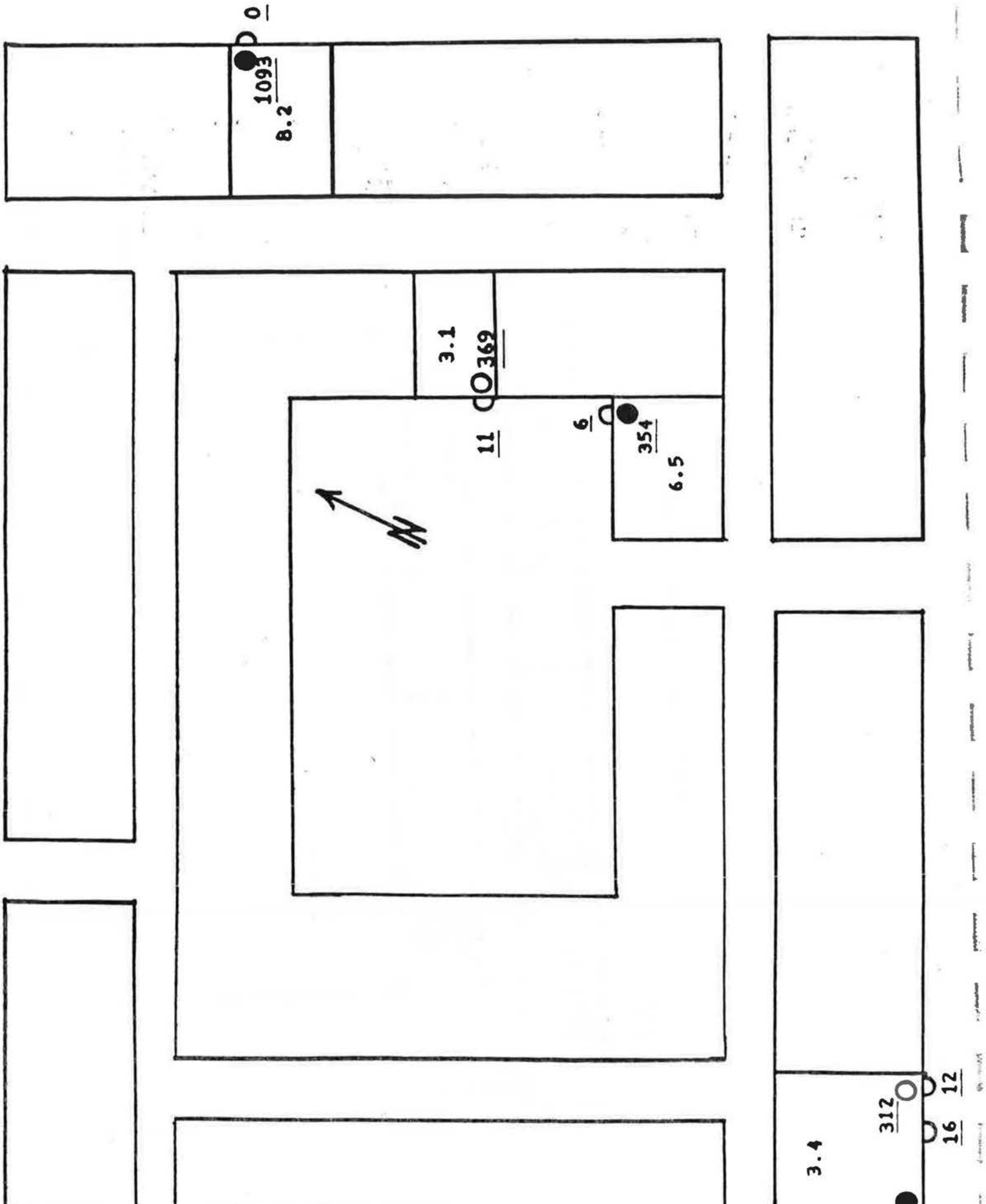
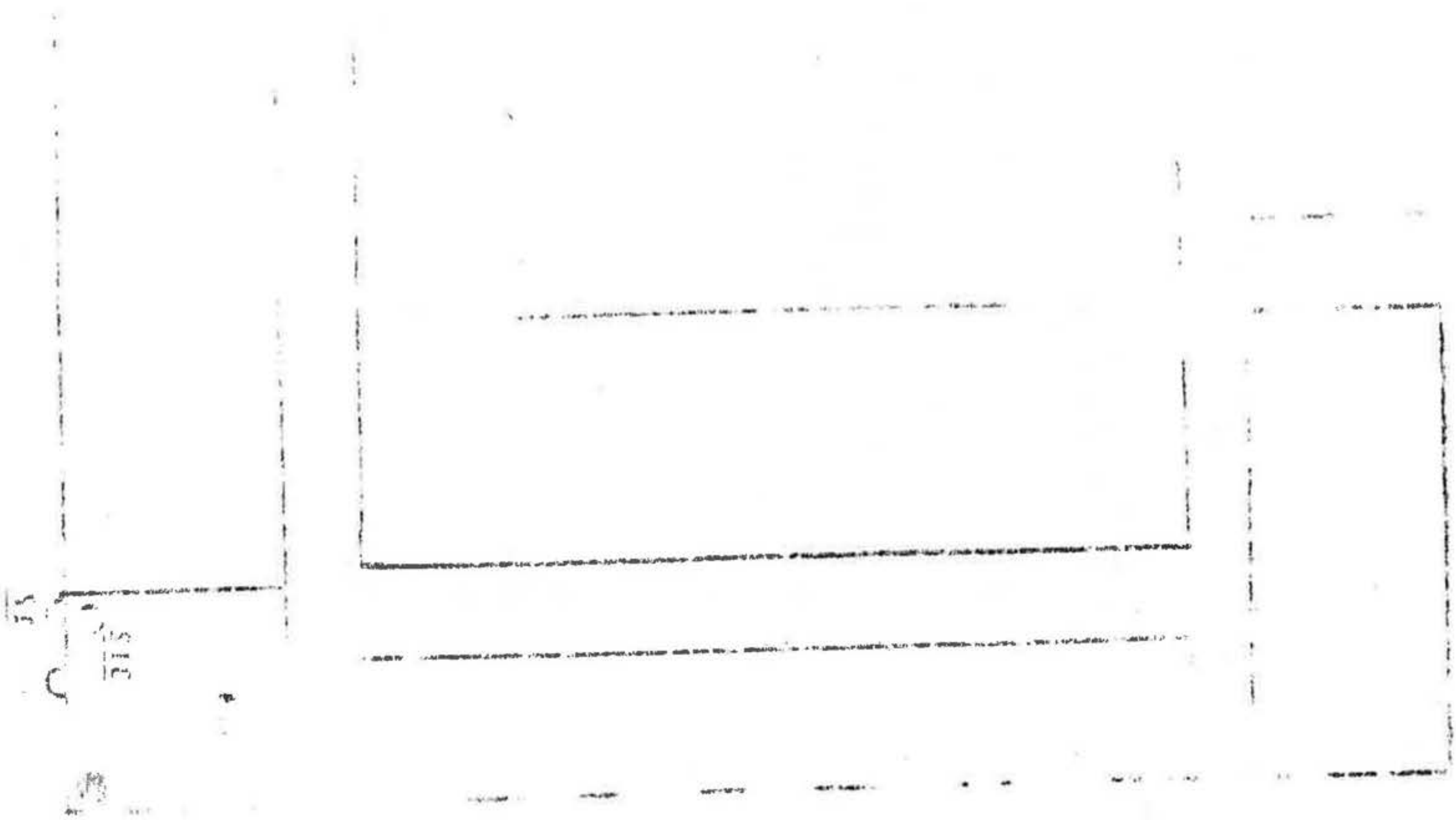


FIGURE 5. Cannon Road Elementary School - Indoor radon levels proportional to sub-slab radon levels due to equivalent HVAC effects and predominant geologic control

Martin Luther King Junior High School (Figure 6) revealed indoor radon migration through blockwalls 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 blockwall radon levels, showing that second floor radon problems were caused by vertical migration through blockwalls. Sub-slab depressurization with appropriately placed blockwall penetrations remediated the school.



MARTIN LUTHER KING JUNIOR HIGH

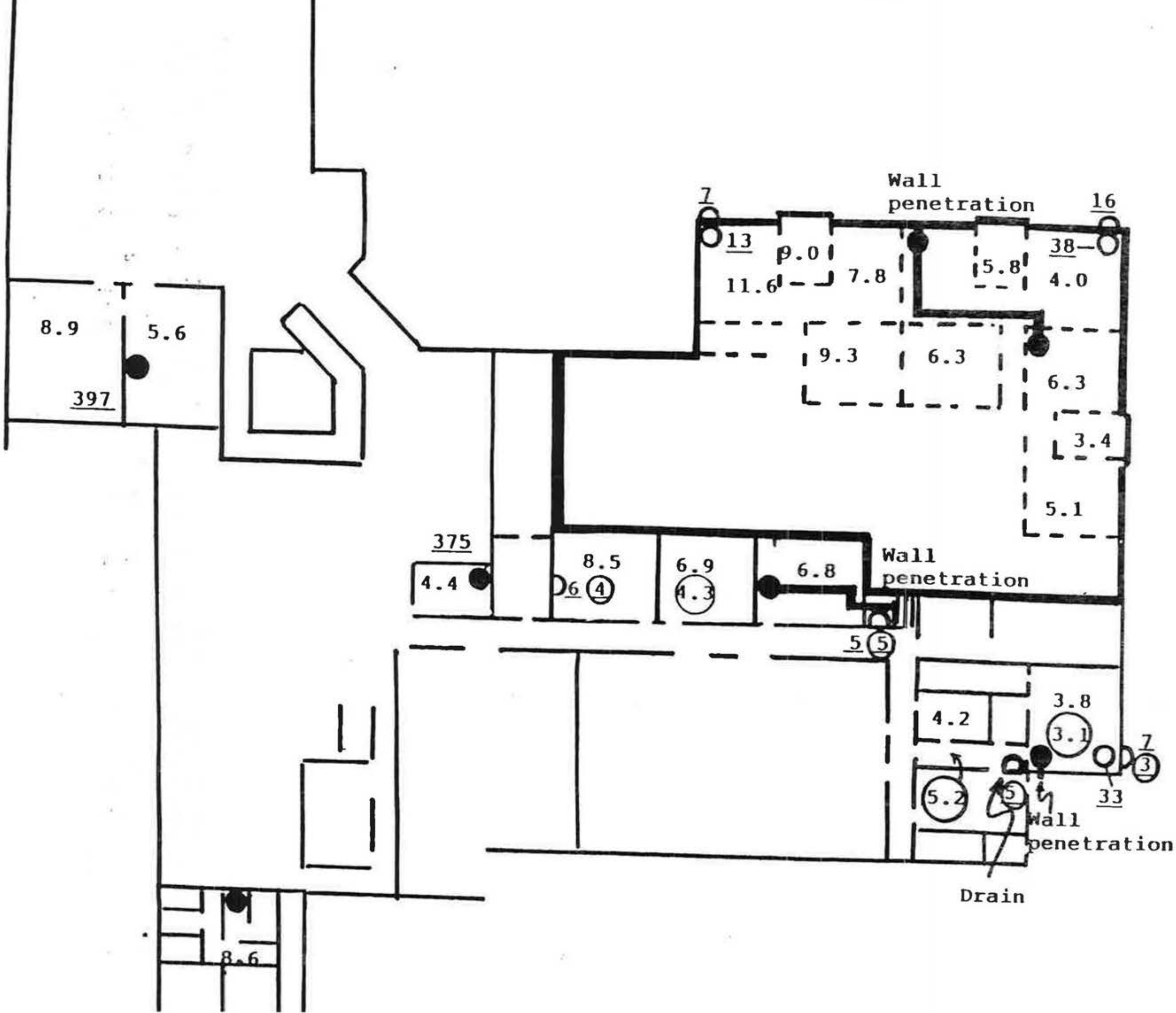
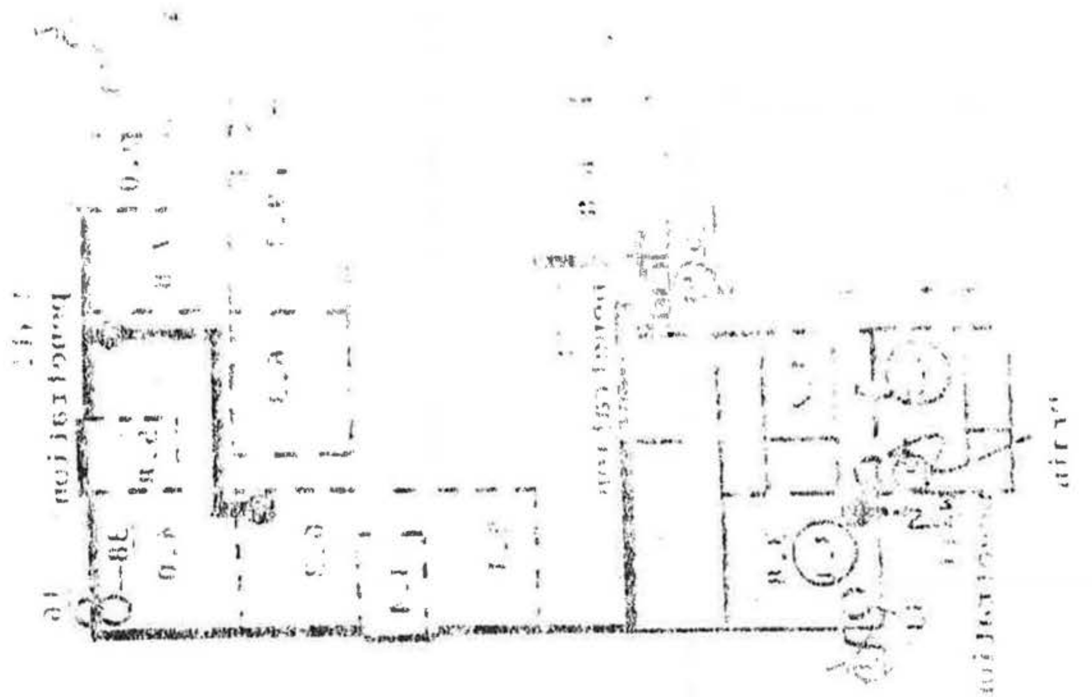


FIGURE 6. Martin Luther King Junior High School - Blockwall radon transport to second floor. Second floor slab-on-grade is outlined in bold with rooms in dashed lines. Where the second floor is above a first floor, radon levels are encircled.

Two schools (Figures 7 and 8) showed approximately equivalent block-wall/sub-slab radon concentrations revealing radon migration into blockwalls directly from the sub-slab source. This shows the need to assess blockwall radon measurements to determine when blockwall penetrations are required based upon high blockwall/sub-slab radon ratios.



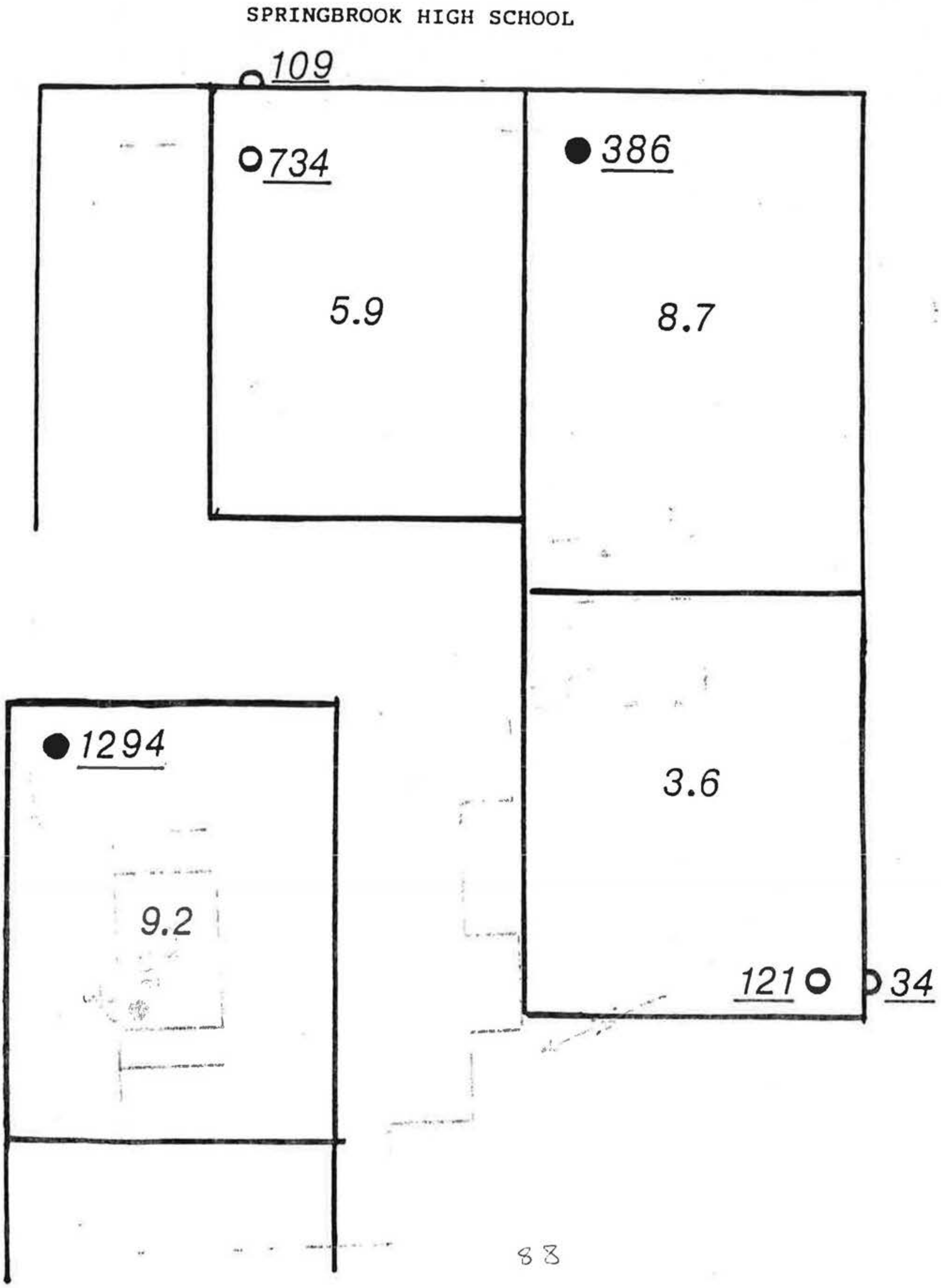


FIGURE 7. Springbrook High School - Blockwall radon concentrations correlating with adjacent sub-slab radon levels.

RIDGEVIEW JUNIOR HIGH SCHOOL

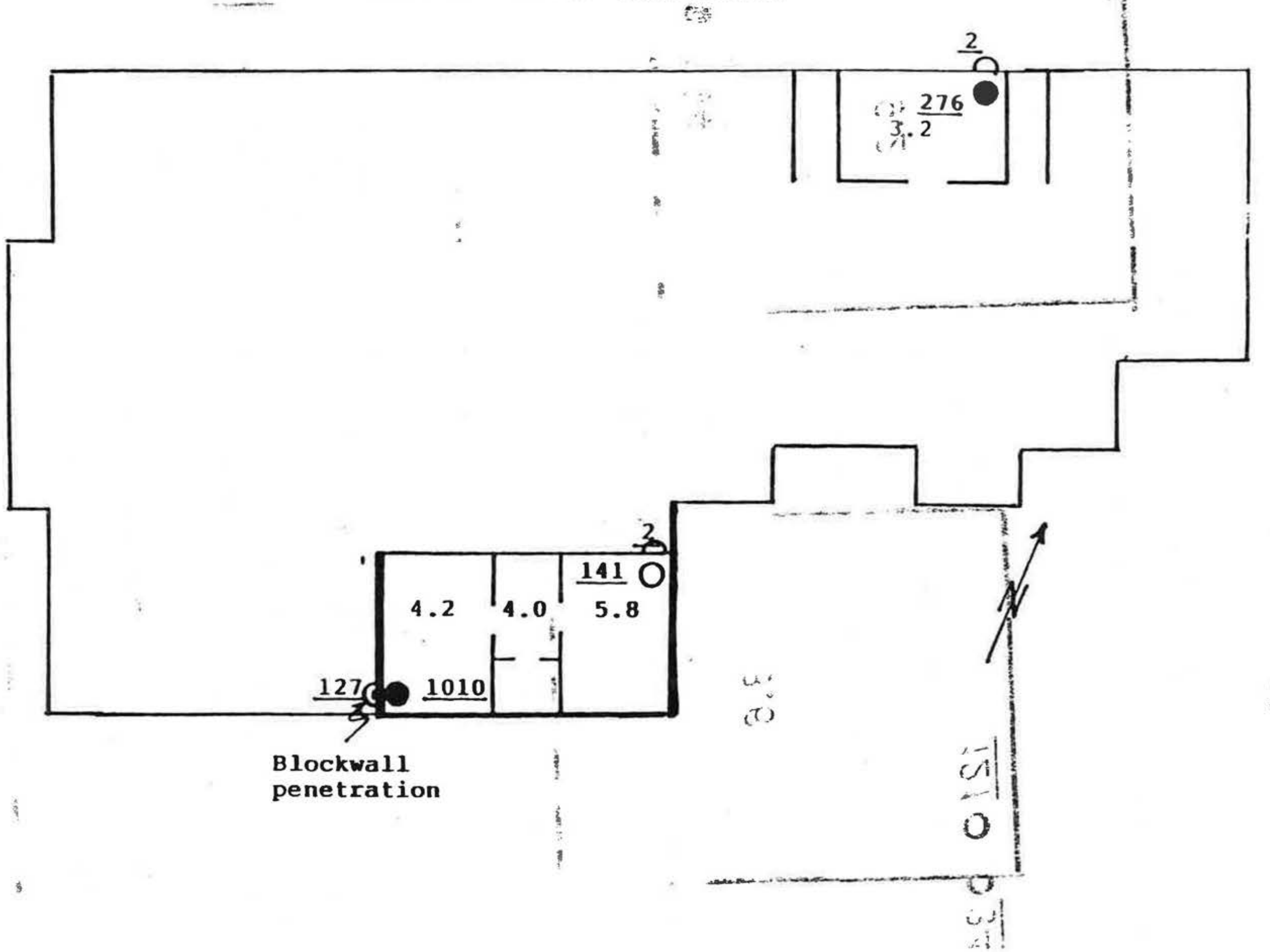


FIGURE 8. Ridgeview Junior High School - Blockwall radon concentrations correlating with adjacent sub-slab radon levels.

In one school radon problems existed over one end of a room (F104) underl by the unvented end of a crawlspace (Figure 9). Table 2 shows the results indoor/outdoor ΔP measurements with a micromanometer. A Tygon tube was run f: the high pressure port of the micromanometer to outside a window, sealed s: with tape, while the low pressure port was open to first the room and then crawlspace. An aquarium stone was attached to the high pressure tube outside minimize wind effects. The differential pressures were then measured in both room and the crawlspace by turning the central HVAC system on with the exha fan off and then with the exhaust fan on. Results reported in Table 2 show th the HVAC system created a negative pressure in the room resulting in radon leve nearly as high as a two-day average within 60 seconds. The exhaust fan, blowi from the room into the crawlspace, diminished this effect. In the crawlspac the HVAC system created an equal negative pressure with the exhaust off t higher radon levels. However, the exhaust fan created a positive pressure in t crawlspace greatly diminishing the radon levels. Theoretically pressurizing t crawlspace with outside air would optimally reduce crawlspace radon level However warm summer outside air entering the cool crawlspace causes condensati problems so remediation was achieved by adding another crawlspace vent below t problem room and running an exhaust line from a roof-mounted fan into t crawlspace, as shown in Figure 9, to draw radon from the crawlspace at a hi enough rate to overcome the increase in radon levels from depressurization.

WHITE OAK MIDDLE SCHOOL

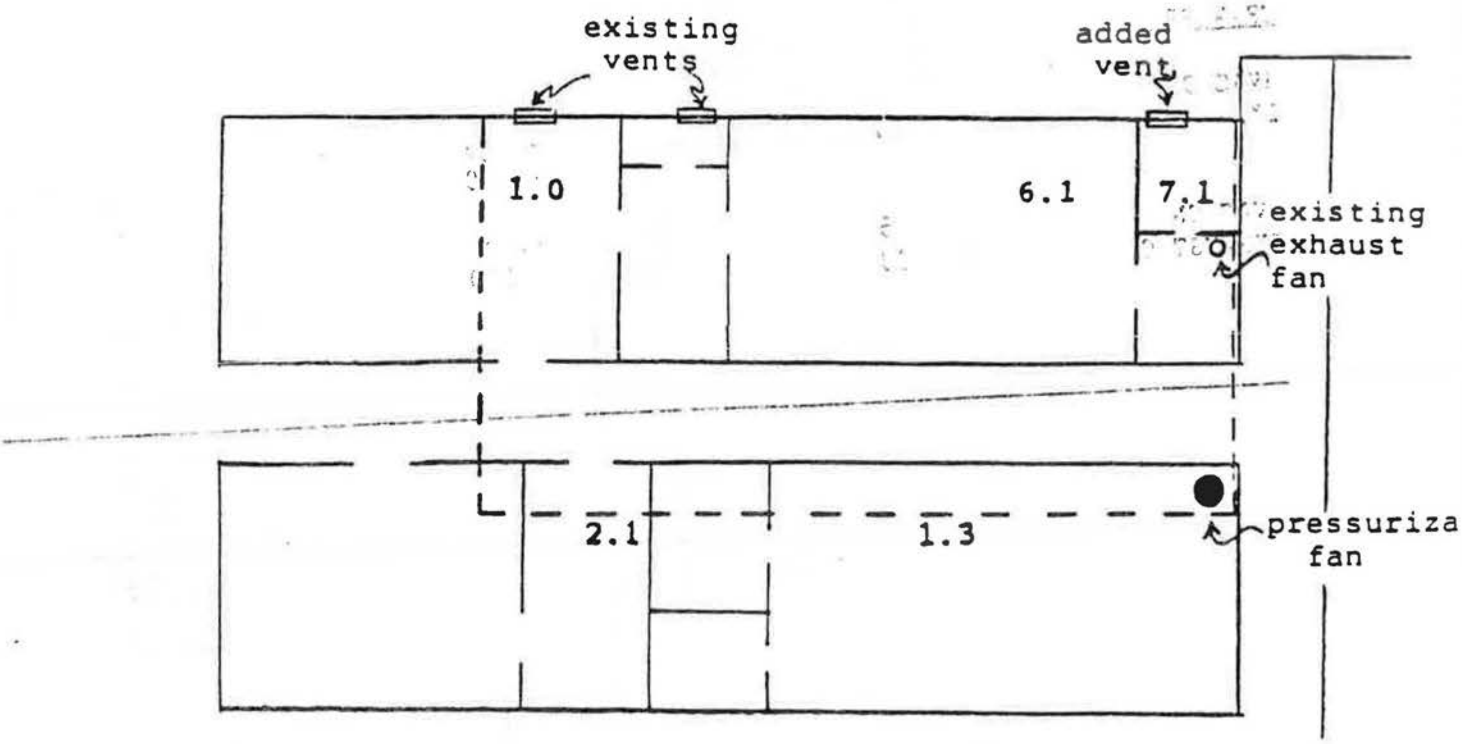


FIGURE 9. White Oak Middle School - Crawlspace area outlined with dashed line. existing exhaust fan exhausts indoor air into crawlspace.

TABLE 2. WHITE OAK MIDDLE SCHOOL - ΔP AND RADON DEPENDENCY ON HVAC AND EXHAUST FAN

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

REFERENCES

1. Hall, S. Correlation of soil radon availability number with indoor rad and geology in Virginia and Maryland. In: Proceedings of EPA/USGS Soil Gas Meeting, September 14-16, 1988, Washington, D.C.

2. Hall, S. Combining mitigation and geology: indoor radon reduction by accessing the source. In: Proceedings of the Annual Meeting of the American Association of Radon Scientists and Technologists, October 15 17, 1989, Ellicott City, MD.