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CREATIVITY APPLIED TO A HARD TO SOLVE RADON PROBLEM: A RESIDENCE ON MINING TAILINGS

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Abstract

A residence built in an area with known previous mining activity had reportedly original radon levels of 275 pCi/L. A radon system was installed and intermittently improved during a period of 18 months by a third party certified radon company. After these original mitigation attempts by others, including the use of a four branch system employing seven radon fans and a double membrane barrier, that were tested to be insufficient, an alternative strategy was devised with continuing testing to reduce the radon level. We will discuss attempts, failures and successes of this mitigation which requires creativity on the mitigator's part to design an efficient system. We will also discuss what was learned about why original mitigation attempts had failed during the first 18 months and will draw conclusions. This talk is aimed to show that certified mitigators must have a certain freedom and must apply creative solutions or else extreme problem situations like this residence may not be able to be mitigated using a simple approach of standard mitigation methods.

Introduction

This is a case study of the radon mitigation performed on a single residence. The house was originally mitigated by another certified company. We became involved in spring 2006 because of a request for a second opinion by the home owner after the first mitigator had tried to mitigate this home intermittently during a period of 18 months. Concerns were voiced by home owner whether it could be that there was something inherently anomalous about constructing a house in this area that allowed a normal radon vent system not to be able to bring the radon concentration level down to below 4.0 pCi/L.

Our pre-investigation showed several aspects of the existing system that were not following applicable guidelines and we recommended appropriate changes, and determined their priority in order to bring radon levels down. A few simple but relevant changes were immediately implemented which seemed to solve the high radon problem. However when winter winds that are characteristic for the area returned, the radon level increased significantly again. Next a more rigorous overhaul of the system was to be implemented as an extension of the work done before.

Status of existing system and early Investigations (Phase 1)

A wood framed ranch style residence, with a crawlspace of 2500 sf and a 300 sf media room in basement to the side of the crawlspace on a slab, was built in the late 1980's in an area that has a history of gold mining.
Original radon concentration values of the house were reportedly 275 pCi/L. A third party mitigation company was asked to mitigate it. The company installed, during a period of 18 months, five independent radon vent pipes using seven ventilators with a double membrane in the crawlspace with two connection points under the media room/office slab. Some of the characteristics of the pre-existing system are in Table 1.

Table 1: Some characteristics of pre-existing system

		Ventilator Location	Pipe Size	End Discharge point	Evacuation location
A	RP265	Boiler Room	4"	Original through roof	South end crawl space, pipe to Geo-mat.
B	FR250	Boiler Room	4"	Garage attic Wall	Drain tile pipe in center of crawl space.
C	2xRP265	Boiler Room	4"	Garage attic Wall	Under slab of Office
D	2xRP265	Attic	6"	Garage attic Wall	Drain tile pipe for West side crawl space.
E	RP265	Attic	4"	Garage attic Wall	Slab of small storage crawl space.

Four ventilators were located in the boiler room which is located immediately above the small section of crawlspace over the slab immediately next to the media room. Three ventilators were placed in the attic of the garage. Fig. 1 gives an indication of the layout of drain tile pipe and geo mat (A) that was used in the crawl space.

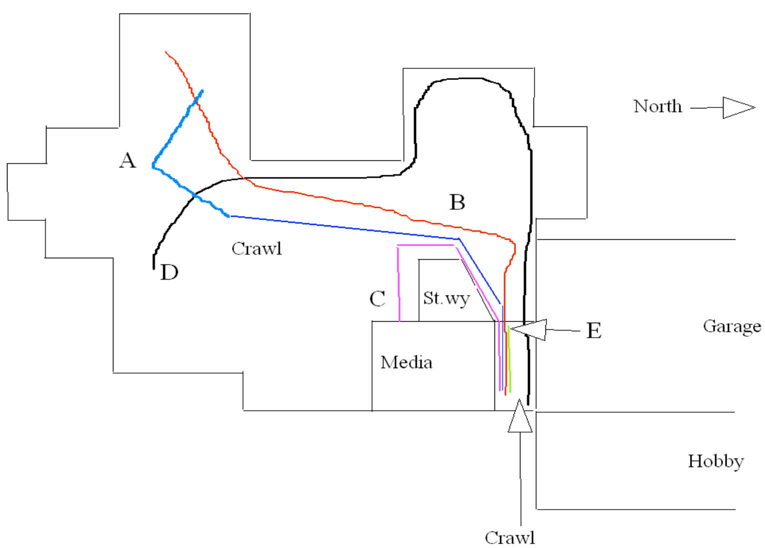

Fig 1: Layout of existing system during first visit. Straight pipe lines are solid PVC pipe. curved lines are drain tile pipe. Pipe A marks the Geo-mat.

After these five active systems were installed Radon levels in downstairs media room had varied between 6 pCi/L and 8 pCi/L as measured with a Safety Siren Pro II radon detector.

The first pipe (A) was discharging the radon above the roof through the attic above the media room. All others terminated through a side wall of a garage attic in the same general area immediately above this roof and near the discharge of pipe A. All additional termination points through side wall were within a foot of each other and within five feet of a dryer and furnace vent. Despite the number of ventilators, ballooning of the radon membrane in Southeast side of crawl space was reported at certain times with strong winds.

Several tests were performed during the visit. Pressure tests through slab of crawl space near the east wall of storage space with the fan on and off resulted in pressure difference across a slab thickness measured to be +0.001"W.C., independent of whether the fan was on or off.
Radon survey test screenings in various areas of the house, in the test hole through the slab and in wall cavities are indicated in figure 1. As part of an initial visit, we performed relative screening flow measurements in various parts of the house. Short three minute test screenings were performed with a femto-Tech CRM410-RS survey instrument capable of taking active air samples with an internal pump. From these screenings we deduced that there are six high radon concentration areas measured as indicated in Fig 2.

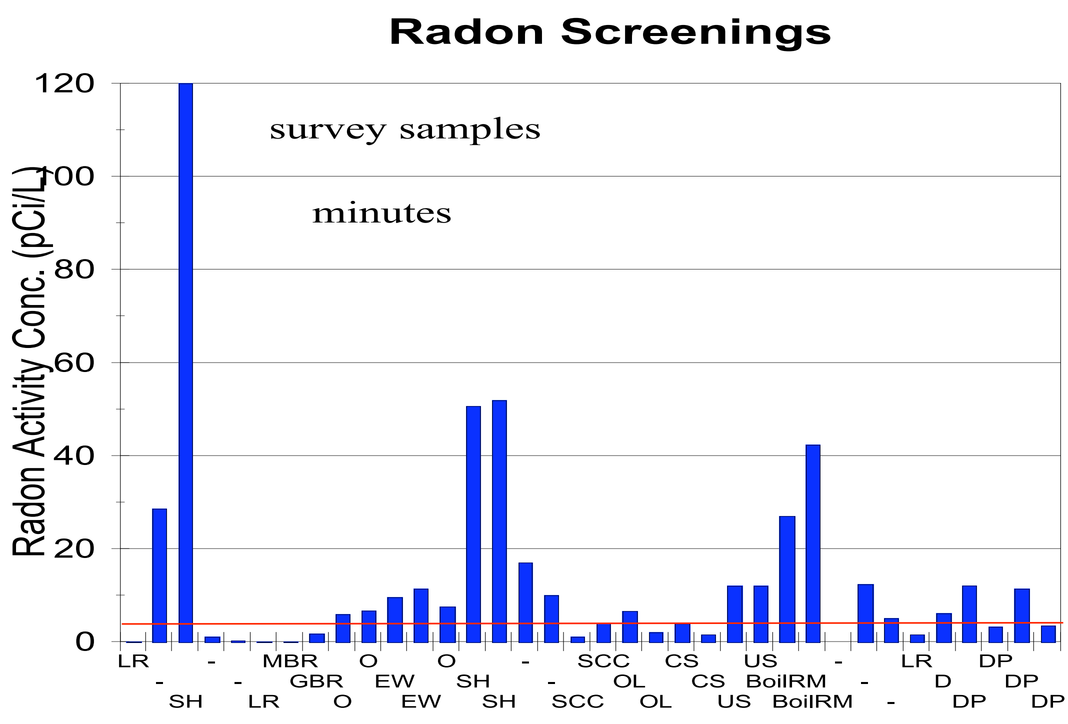

Fig 2; Resulting Test survey screenings. Vertical scale in pCi/L

The following table, table 2, explains the acronyms used in the horizontal axis of the figure:

-	Changed Location, counts not settled to new value
CS	Crawl Space
D	Inside Dryer
DP	Dryer Drain pipe penetration through drywall
EW	East Wall in Office
LR	On table of living room
O	Office in center 14" off floor
OL	Outlet
SCC	Slab Crawl space Center
SH	Hole in slab of crawl space
US	Under Stairway

Table 2: Acronyms for horizontal axis of Figure 2.

Based on manufacturers information of the ventilators we calculated that a maximum air flow can be accomplished by all fans of 1957 cfm, but from an analysis of the vacuum pressures measured below the ventilators in each individual pipe the operational air flow of the combined ventilators in their configuration is 1365 cfm. This actual airflow is still much larger than the airflow normally needed for a house with a footprint of 2500 sf. Normally such a house with a crawl space can be mitigated with a single ventilator and an operation point between 150 and 250 cfm.

Suggested solutions (Phase 1), radon activity concentrations in the spring

Many suggestions were made to decrease the radon levels based on improving the original system. In the boiler room a 10 inch rubber connector above the FR250 ventilator had the wrong diameter, was loose and attached with black duct tape instead of a hose clamp. A fitting rubber clamp was to be arranged.

Vent pipe C was simply placed in a hole under the footer to subslab material from the crawlspace and since this hole was open to the crawlspace no effective removal of air from the sub-slab in media room could be expected. Similarly, vent pipe E from the crawl space with slab section under the boiler room was too close to the footer of crawl space.
The small crawl space under stairway was not completely sealed and no air was removed from the single barrier layer under this part of the crawlspace.

The distribution of the drain tile pipe over the area of the crawlspace was not even and the ends of the drain tile pipe were found not capped off. The radon discharge points above the roof were found to be close to re-entry points. In the main crawlspace the radon barrier was attached to concrete walls with insulating foam instead of caulk. EPA, AARST, ASTM standards all require ventilators not be placed in finished living areas. Placement in a finished boiler room adjoining garage may be useful only if proper year around radon level monitoring is part of the system.

Additional two day measurements with the Safety Siren in the utility room showed 68 pCi/L (with door to garage open!) before the rubber coupler was exchanged. After the new fitting rubber coupler was installed in the spring radon levels decreased to acceptable levels in boiler room and adjoining utility and media room, a radon concentration of 1.6 pCi/L was reported in the boiler room, and 3 pCi/L in the media room. This may have been a limited success because there was not much wind and the temperatures were warmer. Thus it was not clear whether low radon levels would be found during unfavorable wind conditions. Thus it was decided to continue to monitor the radon levels with the Safety Siren detectors.

Radon concentrations the following winter with high winds (Phase 2)

Additional high levels were reported starting next winter (October 2007) when high winds occurred. Values went gradually up to 40 pCi/L in the crawlspace. We continued simultaneous monitoring with Safety Siren detectors that were manually recorded for both crawlspace and basement media room.

Repair and modifications of existing system (Phase 2)

During our visit in the beginning of the winter we chose to compartmentalize the lower section into three compartments in order to better distribute the air removal rate over the entire area. We also decided to remove and reseal the entire upper section of the 24500 sf barrier material. In the process we found a large hole in the lower barrier (3x4 sf), and the perforated drain tile pipe pulling air from the soil was also crossing the lower barrier and was thus communicating to the air gap between the two barriers. (From now on we will refer to this air gap between the two radon barriers by the name “inter-barrier”.)

We also built a separate passive venting system for radon from the inter-barrier to the outside with later options for between the two layers, with options for activation if needed later. In addition, we drilled a new radon extraction hole through the slab of the basement on the far end of crawlspace near the footer to maximize the distance it is removed from the crawlspace in an attempt to prevent a path-way of airflow from the crawlspace. Depressurization tests showed no depressurization even as close as 2 ft away from the hole.
This work was completed in a single four day work session, 14 hours per day with two experienced radon mitigators, during the first heavy snow storm of that winter in the area. Thus, because of the weather conditions, no changes were made to the roof exhaust situation. However, the ventilators were installed in a different configuration to optimize evacuation from the various compartments.

Continued high radon levels: tests and modifications.

Active removal of radon between barriers did not alleviate high radon levels after phase 2 was completed and monitoring was continued. A modification where active flushing was applied to the small inter-barrier volume showed an asymmetry for the direction of the flow in the inter-barrier volume. A 1 ft long rip in the barrier material was found and repaired. Some ice built up near the Tee of the injection intake inside crawlspace was a concern. Further experimenting in which we verified the working of the monitors continued. Ballooning of membrane still occurred at times, which threatened to damage some of the barrier material. Counteracting this force we proposed a pressurization of the crawlspace. From these experiments we also learned that radon concentrations could be reduced in the media room by diluting the air under the slab by the continual injection of air into the radon extraction hole instead of trying to depressurize the sub-slab material. These experiments are shown in Fig. 3 before day number 134.

Adding a third mitigation system in series

To counteract the ballooning of the plastic we brought air from the hobby area continually into the crawlspace in order to pressurize it. The hobby area is a separate room but is

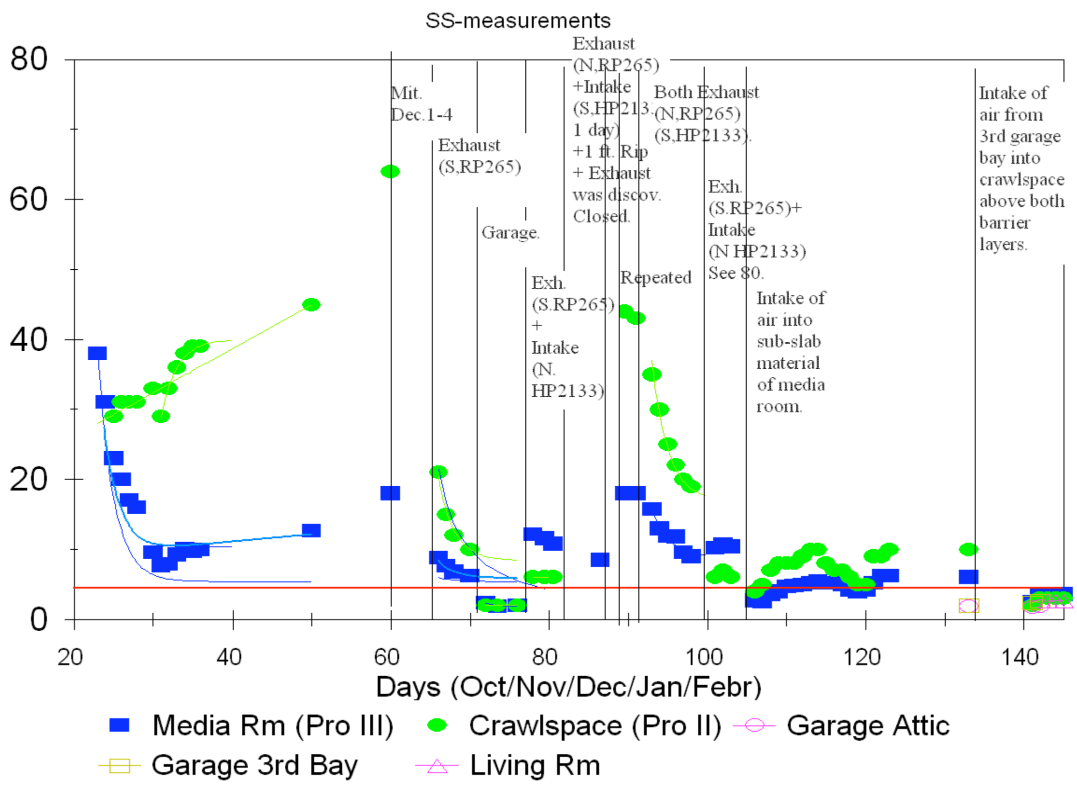

Fig. 3: A series of experiments with the residence using two and later three simultaneous safety siren test devices. The horizontal axis scale is referenced to Oct. 1, 2007.

built against the garage and is referred to as the third bay of the garage. Radon concentrations dropped to low levels in the crawlspace and in the media room in the basement next to the crawlspace, as is shown by the radon concentrations below the reference line at 4.0 pCi/L after day number 134 in Fig. 3.

The final configuration of the radon mitigation system is effectively summarized in Table 3: The pipe letter names (A through E) were the same as before, although ventilators in pipes may have been exchanged and vent pipes F and G were added.
The order of the vent pipes is here rearranged to group individually related radon reduction mechanisms together as can be seen in the last column.

Pipe Branch	*#*	*Ventilator Model*	*Ventilator Location*	*Pipe Diameter*	*End Discharge/Intake Location*	*Area affected*	*Radon Reduction Mechanism*
D	2	2xRP265	Attic	6"	South gable end garage.	Removes air from below both barriers in Area I	Area I exhaust crawl space and building bypass
C	1	RP265	Boiler Rm	4"	South gable end garage.	Removes air from below both barriers in Area II	Area II exhaust crawl space and building bypass
B	1	RP250	Boiler Rm	4"	South gable end garage.	Removes air from below both barriers in Area III	Area III exhaust; crawl space and building bypass
F North	1	HP2133	Crawl space	4"	North Rim joist at floor level.	Injects fresh air in between two layers.	Interface fresh air dilution and crawl space bypass
A South	1	RP265	Boiler Rm	4"	Through roof above media room.	Removes air from between two radon barriers in crawl space.	Interface fresh air dilution and crawl space bypass
E	1	RP265	Attic	4"	South gable end garage.	Injects fresh air under slab of media room	**Sub-slab air dilution** (Not pressurization)
G	1	RP265	3rd Car Garage	4"	Third car garage	Injects fresh air to above both layers into crawl space.	**Crawl space air dilution, and pressurization**

Table 3: Final Configuration in place since 2/10/08 (#133)

Other than the vertical 7 vent pipes and 8 radon ventilators with their characterization and functional details indicated in the table, the system includes the following characteristic elements:

1) two layers of radon barrier material fully sealed in 2500 sf, 6 ft (high) crawl space over a boulder area.

2) three flexible drain tile pipe loops below both layers of radon barrier material. (I: nearest to the entry into crawlspace under boiler room into crawlspace (north); II: mid section; III: far end section from entry (south))

3) two banana shaped sections of flexible drain tile pipe (Approx. 60 ft long), one on the north side and one on the south side of the crawl space.

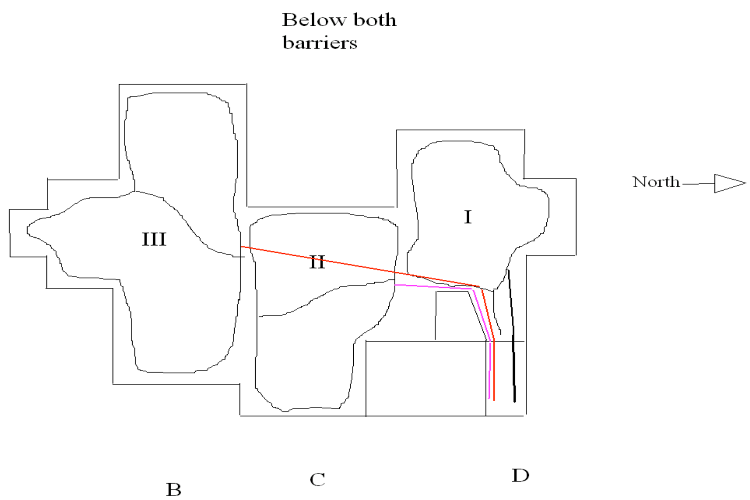

Fig 4: Three independent sub-membrane loops of drain tile pipe under both membranes. Straight pipe lines are solid PVC pipe. Curved lines are perforated drain tile pipe.

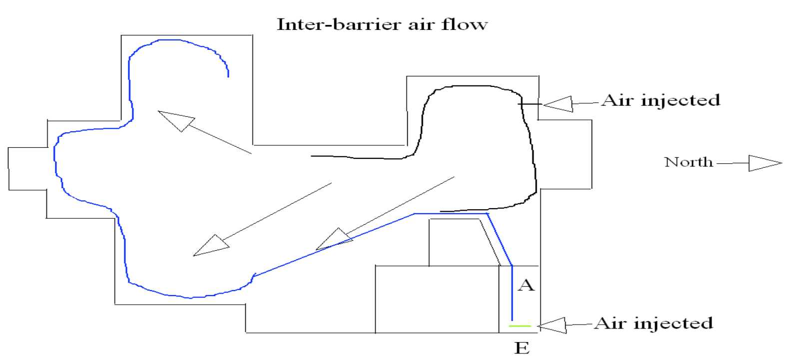

Fig 5: Drain tile pipe layout to dilute and remove radon that makes it past the lower barrier and the corresponding air flow. Through vent pipe A the air is removed. Straight pipe lines are solid PVC pipe. Curved lines are perforated drain tile pipe.

Experiments with this showed that airflow from north to south between the two layers of radon barrier could be increased by adding a few short sections (5 ft) of drain tile pipe in certain areas in the inter-barrier in order to help separate the top and bottom layers of the barrier material at those locations

History of area and cause of the problem

This wood framed home was built in the late 1980's in an area that is known for previous extensive gold mining activities. When in 1859 the first prospector found gold (worth $0.13), the gold rush in this area started.

Manmade extensive gold mining activity, with dredging, from 1898 to 1942 using 9 dredge boats on the Swan River, French Creek and Blue River were responsible for 50 feet deep piles of dredge tailings. The residence stands over the physical area where dredge tailings of the gold mining industry in Swan River Valley near Breckenridge were located. An aerial photo taken in the early 80"s, before the house was built, showed the dredge tailings in piles of an estimated 100 ft by 40 ft. size. The dredging process has removed the fine materials out of the sub-soil and transformed the sub-soil of the riverbed, making it into a geological structure that most resembles "a bathtub with marbles". This causes the river for large parts of the year to stream entirely under ground, according to a former City Engineer of Breckenridge, and before 1984 the river could only been seen in the town above the dredge tailings after mountain snow runoff.

The fact that a large volume of underground air connects to the interior air of the house is corroborated by three facts: First, the owner of the construction company that built the house said that tremendous winds could be felt through the crawlspace access opening into the house during construction. Second, even with seven fans and a total calculated operational air removal rate of 815 cfm for the combined operating flow of B, C, and D in the final configuration, the system was not always able to overpower the rate with which air rushed into the building from under the barrier. This was simply proven by observing that the radon barrier at times during our work was ballooning when the mitigation system was operating and the lower radon barrier layer was already completely sealed. Third, vacuum pressure tests conducted as close as 2 feet away from the suction hole through the slab part of this house were not able to detect a measurable negative pressure meaning that vacuum pressures at this close distance were smaller than -0.001" W.C.

This is a different manmade radon problem than that which has been identified in the prior literature. It is different from the processing of uranium mill tailings into building materials. Instead it is caused by continuing excavation of the land, processing 1 million troy ounces of gold (31,000 kg) from this area. This mining activity over a period of 44 years has sifted all small materials out of the ground, forming lakes and river beds that were refilled with head size boulders which were the tailing products disposed of by the industrialized gold mine dredging process. The last major gold mining operation in Breckenridge operated sporadically until 1973. Since 1984 reworking of the area into a natural landscape has returned the dredges but not the finer particulates of the sub-soil.

Houses are now standing on areas that for a radon problem should be treated with the similar methods for testing and mitigation as karst areas, where radon can be moved into a house via air movement through large and small caves over long distances and the residential radon levels can be strongly dependent on factors as wind and season. For these areas it is advisable that repeated tests throughout the year or long term tests should be conducted as valid tests. The same recommendation should be observed in this area. In other words a radon system working at a given time may not be working at a different time, and only a year long test will tell what the yearly average radon level in a particular house will be.

This case shows that, when confronted with this type of manmade radon problem, in order to remove air at a sufficient rate from under the barrier (or slab) multiple depressurization systems may be needed; in this case up to three systems in series. The decisions how to proceed in this research were based on an existing system and may have been different if we had been confronted with the problem as a first mitigator.

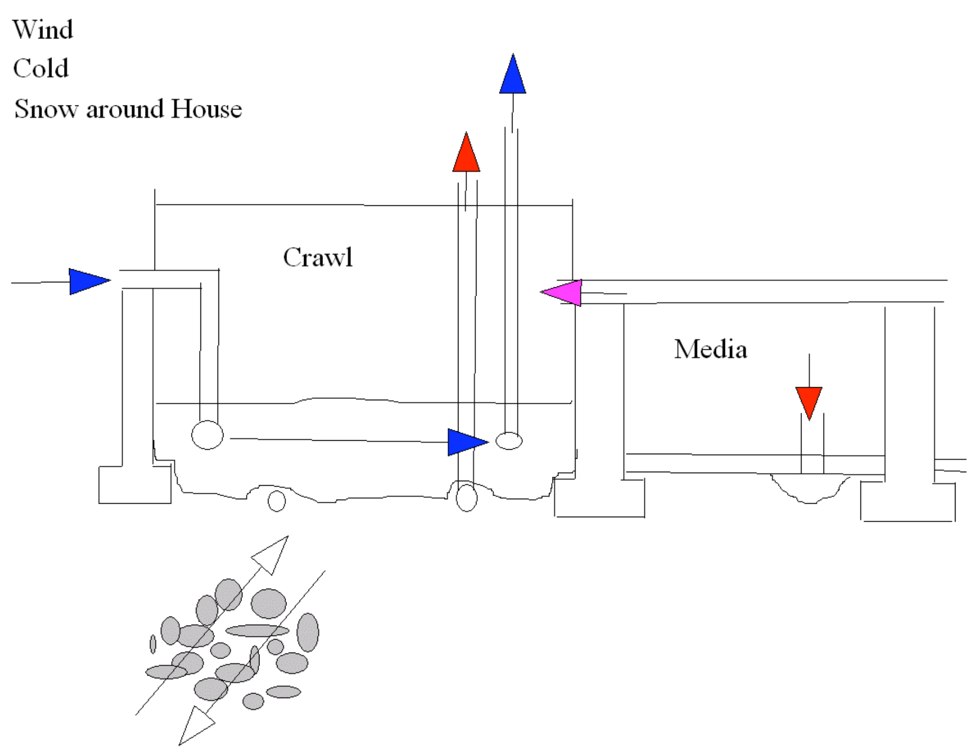

Fig. 6: Final configuration of the radon system in this residence on dredge tailings that even during unfavorably weather conditions maintained a radon level below EPA's guideline. The configuration of four radon reduction mechanisms is given in table 3 and the sub-membrane drain tile pipe layout is shown in Fig. 4 and 5.

Conclusions for future radon systems in this or a similar area

With the knowledge acquired about the manmade substrate and when working from the start on mitigating a house in this area we could have started with the installation of a single layer hermetically sealed radon barrier with an energy (or heat) recovery system above it in the crawlspace. This latter method may also be the appropriate method when working with a slab in an existing home.

In new home construction in this area it is advisable, in my opinion, to have a radon mitigation company with experience placing a hermetically sealed double-layer of radon barrier material under a slab with a layer of sand or gravel immediately above it, before the slab is poured. In addition, all slab openings should be sealed on expansion joints grooves and penetrations, in which case a slight pressurization of this well-sealed layer of material that resides between slab and barriers can be sufficiently pressurized with a smaller air volume rate (possibly accomplished by a single fan.) Such a system accomplished an air shield against the radon otherwise dragged up by air convection. It does not protect against pure diffusive infiltration, unless also a small relief valve is built in at an appropriate location opposite to the pressurization point in order to take advantage of dilution of the air under the slab.