Supplemental Guidelines for the Evaluation of Structural Vapor Intrusion Potential for Site Assessments and Remedial Actions Under the Inactive Hazardous Sites Branch 21 June 2011

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I. General:

An evaluation of vapor intrusion potential is required anytime an existing building, or a lot where a building could be placed in the future, is located within 100 feet of groundwater or soil contamination. An evaluation of distances greater than 100 feet may be needed if there are significant preferential pathways that may be conduits for vapors toward a structure. This requires an awareness of the geology of the area and the location of utility corridors. Vapor intrusion evaluation is required for both residential and non-residential structures. Vapor intrusion evaluation is not required for groundwater contamination when the contaminant concentrations do not exceed the 15A NCAC 2L standards unless all the following conditions exist:

(1) concentrations exceed one order of magnitude of the groundwater screening values (***Acceptable Groundwater Concentrations*** on the IHSB Vapor Intrusion Screening Tables,
(2) for areas of concern fully delineated with multiple sample points, more than one sample point meets the criteria in (1), otherwise if any sample point meets the criteria in (1), and
(3) residential property exists within 100 feet of the lateral edge of the concentration criteria specified in (1).

At landfill sites where waste volumes are too large for removal, the waste itself can pose a vapor intrusion potential. Each landfill must be evaluated for vapor intrusion potential. See additional Inactive Hazardous Sites Branch (IHSB) "Guidelines for Addressing Old Landfills and Dumps."

All hazardous substances with Henry's Law Constants above 10^{-05} atm m^3/mol are suspect. Aside from the analytes on a typical volatile scan, qualifying chemicals can include mercury, ammonia, and hydrogen sulfide, PAHs, PCBs, dioxins and other semivolatiles. Refer to Table 1 in either of the USEPA guidance

documents Draft Guidance for Evaluating Vapor Intrusion To Indoor Pathway From Groundwater, November 2002 or User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings, February 2004 for an extensive list of contaminants that qualify. **Do not use the screening tables in the above US EPA guidance documents as they do not take into account additivity of effect of multiple chemicals. Instead use the IHSB Vapor Intrusion Screening Tables available on the web.**

Where a contaminant of concern (present in groundwater, soil or waste) is a chemical currently in use in a commercial/industrial structure, OSHA would regulate the concentration allowed in indoor air. However, when the chemical ceased to be used in the future, it would no longer be regulated by OSHA. The space may not meet IHSB indoor air numbers. More often than not, it will not be possible to determine how much of the chemical is the result of the use of the chemical versus off-gassing of contaminated media in the subsurface at the time decisions are being made on remediation needed at the site. To protect future occupants of the building from exposure to contaminants in indoor air when the OSHA standards cease to apply at a currently OSHA-regulated structure, the remediating party is required to use the Screening Steps outlined in this guidance up to, but not including, the testing of indoor air. If the structure fails all the screening steps leading up to the testing of indoor air but meets OSHA limits, contaminated media at the site must nevertheless be remediated so that subslab vapors meet IHSB screening criteria or land use restrictions must be placed on the property. Refer to Section III for further information.

II. Screening Steps:

For properties with both groundwater contamination and soil contamination within 100 feet of an existing or planned structure or a vacant lot, the remediating party will need to evaluate the potential for vapor intrusion from both soil contamination and groundwater contamination. Follow the steps in each of these respective sections.

In any cases where contaminant concentrations are increasing toward a receptor location, continued screening/monitoring will be required at least annually.

NEVER CONDUCT INDOOR AIR SAMPLING AS THE FIRST STEP. Proceed stepwise as follows:

A. Vapors From Groundwater Contamination:

(1) If the structure evaluated has basement space below the water table, proceed with sampling of air in that space. Otherwise proceed as follows.

(2) Compare the highest groundwater concentrations present within 100 feet of the structure to the ***Acceptable Groundwater Concentrations*** on the IHSB Vapor Intrusion Screening Tables (the numbers are based on a cancer risk of 1.0 E-05 and a HQ of 0.2). There are numbers for residential structures and commercial/industrial structures. Use the residential ***Acceptable Groundwater Concentrations*** to screen commercial structures where children spend significant time such as schools and day care facilities. Vapors from groundwater contamination do not have to be evaluated if the 15A NCAC 2L standards have been met unless contaminant concentrations exceed one order of magnitude of the ***Acceptable Groundwater Concentrations*** within 100 feet laterally of residential property. If a particular volatile chemical is not found on the table, contact

the IHSB about determining a screening number for that chemical. If the concentrations in groundwater exceed the generic screening numbers, the IHSB can calculate the actual collective cancer risk and Hazard Index posed by the contaminants and compare to acceptable cancer risk/non-cancer hazard targets. For IHSB to determine site-specific risk/hazard, the remediating party will need to provide the names of the contaminants and the highest concentrations detected in groundwater within 100 feet of the existing or future structure. If the contamination in groundwater meets the acceptable risk targets (1.0E-04 risk collectively for carcinogenic contaminants and a cumulative Hazard Index of 1 for non-carcinogenic contaminants), no additional work is needed unless the contaminant plume is migrating toward a structure/lot or other site conditions warrant conducting further evaluation. If the risk/hazard exceeds IHSB targets, proceed to the next step.

(3) If the detected groundwater contaminant concentrations fail the above screening, soil gas samples will need to be collected. This step involves the collection of soil gas samples outside the perimeter of the structure. **Note that if the highest groundwater concentrations are directly beneath a structure, a subslab gas sample must be collected instead. Proceed to step (4) for the structure. Otherwise the following protocol should be used for locating samples.** Samples can be collected (must select multiple locations) at (a) the properties-with-structures and vacant building lots having the highest groundwater concentrations or closest in proximity to the contaminant plume or (b) on the source property, in the area with the highest groundwater contaminant concentrations. Each and every lot or home does not require soil gas testing. Those deemed to have the greatest potential for vapor intrusion along with a representative number of the remainder should at a minimum be evaluated. If the geology is highly variable, collect the sample as close to the structure as possible. Otherwise, collecting soil gas samples in the area where the groundwater concentrations are the highest, regardless of proximity to a structure, would provide the most conservative evaluation. Samples should be collected as close to the water table as possible (but outside the predicted capillary fringe) and always at depths of at least five feet below ground surface (to avoid barometric pumping influences). If collecting in area described in (a), an understanding of the local geology and the location of utility corridors that may be preferential gas migration pathways is essential. If these potential pathways exist, a sample just above the water table near the structure may not be adequate. Vapors may have migrated from the source area into utility corridors and traveled in the shallow subsurface to the structure. If such conditions exist, proceed to step (4) or instead sample at area (b). Also, if there is less than five feet of depth to groundwater, proceed to step (4). Otherwise compare the soil gas concentrations for samples collected in step (3) to the ***Acceptable Soil Gas Concentrations*** on the IHSB Vapor Intrusion Screening Tables. If the contaminant concentrations exceed the generic screening numbers, the IHSB can calculate the actual collective cancer risk and Hazard Index posed by the contaminants and compare to acceptable cancer risk/non-cancer hazard targets. If the soil gas sample meets the acceptable risk targets (1.0E-04 risk collectively for carcinogenic contaminants and a cumulative Hazard Index of 1 for non-carcinogenic contaminants), no additional work is needed unless the contaminant plume is migrating toward a structure/lot or other site conditions warrant conducting further evaluation. If the risk/hazard exceeds IHSB targets, proceed to the next step.

(4) Conduct the testing prescribed below depending on whether the lot is vacant or has a structure.

Vacant Lots: State law requires remediation of contaminated groundwater to the 15A NCAC 2L groundwater standards, thereby mitigating vapor threats for future buildings. If any groundwater contamination above the lower of the 15A NCAC 2L standards or the ***Acceptable Groundwater Concentrations*** on the IHSB Vapor Intrusion Screening Tables exists within 100 feet of a planned building at the time construction will be initiated, mitigation systems should be installed as part of the building construction. Testing of subslab or crawlspace air as described next should follow any building construction.

Existing Structures: For existing structures, if the soil gas concentrations exceeded IHSB risk targets, the next step is the collection of gas samples from either just below a slab/dry basement foundation or within a crawlspace. Note that some owners may not permit the subslab testing as it requires drilling through the slab. If so, proceed to step (5).

When to Collect Subslab or Crawlspace Samples: Samples must be collected during worst case conditions. Cold, windy weather produces the worst case conditions. When the exterior of the building is colder than the interior, the heating of the indoor space produces a chimney effect and air can rise into the structure. Relative under-pressurization within a building can also induce air flow into the building. This pressure difference can result from barometric pressure changes, high winds and many other factors. How well a building is sealed at windows and doors versus the foundation and floor are also factors. Prediction of whether the air being introduced is coming primarily from the outside air or from air from soils beneath the structure can be difficult. Also, planning around barometric pressure and wind changes can be difficult. Therefore when planning for a worst case test, the IHSB will focus primarily on temperature. Sample when the average highs are less than 60 degrees (Fahrenheit). Generally that means mid-Nov through mid-Mar for the mountains and upper piedmont and mid-Dec through mid-Feb for the lower piedmont and coastal plain. Note that in areas where the depth to groundwater varies greatly during the year, you may also need to sample when the water table is high. High concentration conditions may call for immediate testing, with another sample to follow during cold weather or high water table. At least one sample event should occur during worst case conditions.

For crawlspace samples, an exterior upwind background sample must be simultaneously collected. Background concentrations will be subtracted from the crawlspace sample results. The results for crawlspace tests should be compared to the ***Acceptable Indoor Air Concentrations*** on the IHSB Vapor Intrusion Tables.

The results for subslab tests should be compared to the ***Acceptable Soil Gas Concentrations*** on the IHSB Vapor Intrusion Tables.

If the sample contaminant concentrations are below, but within one order of magnitude of the screening concentrations on the tables for crawlspace or subslab testing, at least one other sample event will be required.

If the contaminant concentrations exceed the generic screening numbers, the IHSB can calculate the actual collective cancer risk and Hazard Index posed by the contaminants and compare to acceptable cancer risk/non-cancer hazard targets. If each sample event meets the acceptable risk targets (1.0E-04 risk collectively for carcinogenic contaminants and a cumulative Hazard Index of

1 for non-carcinogenic contaminants), no additional work is needed unless the contaminant plume is migrating toward a structure/lot or other site conditions warrant conducting further evaluation. If the risk/hazard exceeds IHSB targets, proceed to the next step.

(5) If the above testing exceeds the allowable risk, conduct indoor air testing. An exterior upwind background sample must be collected with the indoor air sample. Upwind background samples should be initiated one hour prior to the collection of indoor air samples unless estimates of building exchange rates indicate a shorter or longer delay is appropriate. The time lag between the collection of the background and the test sample should allow for one exchange volume to have occurred.

After subtracting for background concentrations, if the contaminant concentrations do not exceed the ***Acceptable Indoor Air Concentrations*** on the IHSB Vapor Intrusion Tables (1.0E-06 and HI of 1) and the sample was collected during worst case conditions, no further vapor study is required unless the groundwater contaminant plume is advancing in the direction of the structure or other site conditions warrant conducting further evaluation. If the contaminant concentrations correspond to a collective cancer risk of between 1.0E-06 to 1.0E-04 and are within a Hazard Index of 1, then at least one additional test is required. A second test should be scheduled during worst case conditions. Thus, a minimum of one sample event during worst case conditions and two if concentrations fall within the risk range, are required. If the samples do not exceed the screening numbers but a contaminant plume is migrating toward the structure, periodic soil gas testing will be required. If any sample exceeds the 1.0E-04 cancer risk limit or a Hazard Index of 1, conduct abatement.

When to Collect Indoor Air Samples: While samples should be promptly collected, if the time of collection falls outside the worst case temperature collection period, additional testing will be required during the worst case conditions (see paragraph on when to collect subslab or crawlspace samples). The HVAC system effects should be evaluated prior to sampling. If the system causes a negative pressure, this may induce more flow into the building. That flow may be from exterior "clean" air or from subsurface contaminated air. If the system cycles frequently causing more air exchange, air contaminant concentrations could be increased or decreased depending on whether the air is from a cleaner exterior or from the contaminated subsurface air. When the system cycles infrequently, there is less introduction of outdoor air or subsurface air. Thus, multiple samples at different times of the year may be needed to cover the times when the system regularly cycles and when it is not being used during more temperate weather.

Indoor Air Results	**Notes**
< 1.0 E-06 cancer risk and < 1 HI	No further screening required if sampled during worst case event-see this guidance for further details*
1.0 E-06 to 1.0 E-04 cancer risk and < 1 HI	Minimum 2 sample events*
> 1.0 E-04 or >1 HI	Mitigation required

* If groundwater contamination is advancing toward structure, continued periodic testing will be required.

B. Vapors From Soil Contamination:

Sites with soil contamination only may also require evaluation of vapor intrusion potential into current and future structures. Site-specific conditions should be weighed to determine if testing for vapor intrusion potential is warranted. Three primary factors in this consideration are areal extent of the contamination, the total volume of contaminated soils and the contaminant concentrations. For example, contamination below about 10 ppm or the IHSB unrestricted use preliminary health-based remediation goals and very limited in areal and vertical extent would generally not require further investigation. A decision to test should be a weighing of these and other relevant factors.

(1) Vacant Properties Within 100 Feet of the Contamination:

For vacant lots with soil contamination, the depth of soil gas samples should be established as follows. If the depth of greatest concentration is less than five feet below ground surface and detectable contamination extends to at least five feet below ground surface, then one soil gas sample should be collected at the depth of highest soil contaminant concentrations and a second soil gas sample should be collected at five feet of depth. The shallower sample may draw air from the surface. If the depth of highest soil contamination is deeper than five feet, then one soil gas sample should be collected at that depth. For lots without soil contamination, but within 100 feet of soil contamination, the depth of soil gas testing should be determined taking into account the location of conduits and the local geology between the vacant lot and the source area.

Alternatively, a remediating party can record land use restrictions that will require certain types of building vapor barriers or venting systems and may prohibit certain types of structures such as single family residences, in place of having to treat or remove the soil to eliminate the vapor intrusion risk. Regardless, the remediating party must meet the two other soil remediation goals: direct contact risk levels (restricted or unrestricted use) and protection of groundwater criteria.

(2) Properties With Structures Within 100 Feet of the Contamination:

For properties with existing buildings within 100 feet of the contamination, soil gas testing should be conducted next to the building. The sample should be as close as possible to the structure and on the side of the building closest to the contamination. Samples should be collected at five feet below ground surface. **Note that if the building is located on top of the soil contamination, then a subslab or crawlspace sample should instead be collected as described in item (4) for groundwater contamination.** The results for crawlspace tests should be compared to the ***Acceptable Indoor Air Concentrations*** on the IHSB Vapor Intrusion Tables. The results for subslab or soil gas tests should be compared to the ***Acceptable Soil Gas Concentrations*** on those tables. If the contaminant concentrations do not exceed these levels and the sample was collected during worst case conditions, no further vapor study is required. If the contaminant concentrations correspond to a collective cancer risk of between 1.0E-06 to 1.0E-04 and are within a Hazard Index of 1, then at least one additional test is required. A second test should be scheduled during worst case conditions. If any sample exceeds the 1.0E-04 cancer risk limit or a Hazard Index of 1, indoor air testing will be needed. If that is the case, follow the requirements specified in item (5) for groundwater contamination.

III. Remediation/Mitigation:

A. General:

If a structure fails indoor air testing, relevant analysis of the building construction should be conducted in association with a mitigation proposal.

Any time commercial/industrial vapor intrusion screening numbers are used, land use restrictions will be required. If commercial/industrial sites meet Branch residential vapor intrusion screening numbers, then no land use restrictions are required.

A remediating party can record land use restrictions that will require certain types of building vapor barriers or venting systems and may prohibit certain types of structures such as single family residences, in place of having to treat or remove the soil to eliminate the vapor intrusion risk. Regardless, the remediating party must meet the two other soil remediation goals: direct contact risk levels (restricted or unrestricted use) and protection of groundwater criteria.

B. Structures Not Meeting Indoor Air Targets:

If vapors fail to meet indoor air targets, then engineering controls to mitigate exposure along with land use restrictions will be required. Land use restrictions should at a minimum specify that:

- The owner shall conduct periodic indoor air tests to ensure any vapor mitigation system installed is working properly.
- The annual owner certification must state that the vapor mitigation system has been inspected on some schedule approved by DENR and is working properly and include the indoor air sample results.
- The structure shall not be used for any purpose if mitigation systems are not installed or found not to work.
- When the building it demolished, new construction be required to have engineering controls for the prevention of intrusion of unacceptable levels of contaminated vapors.
- For any new construction, the indoor air space be tested annually for 10 years or for some period the owner has demonstrated will allow for full settlement of the structure. If vapor mitigation systems other than barriers are incorporated into the construction, continued periodic monitoring of indoor air beyond 10 years will be required.

C. Structures With OSHA-Regulated Chemicals of Concern:

Where a contaminant of concern (present in groundwater, soil or waste) is a chemical currently in use in a commercial/industrial structure, OSHA would regulate the concentration allowed in indoor air. However, when the chemical ceased to be used in the future, it would no longer be regulated by OSHA. The space may not meet IHSB indoor air numbers. More often than not, it will not be possible to determine how much of the chemical is the result of the use of the chemical versus off-gassing of contaminated media in the subsurface at the time decisions are being made on remediation needed at the site. To protect future occupants of the building from exposure to contaminants in indoor air when the OSHA standards cease to apply, the remediating party is required to use the Screening Steps outlined in this guidance up to, but not including, the testing of indoor air. If the structure fails all the screening steps leading up to the testing of indoor air but meets OSHA limits, contaminated media at the site must nevertheless be remediated so that

subslab vapors meet IHSB screening criteria or land use restrictions must be placed on the property. If vapors fail to meet subslab targets (for cases where the chemical is currently being used in the building) land use restrictions must be placed on the property covering the following:

- The annual owner certification must state that the chemical is still in use and being regulated by OSHA.
- The owner shall notify DENR within some specified period if contaminants of concern are no longer regulated by OSHA. The owner shall cease to use the building or shall conduct indoor air testing specified by DENR.
- If the testing fails IHSB targets, within timeframes approved by DENR, the owner shall install mitigation systems in the building and retest indoor air or cease to use the building.
- Owner shall conduct periodic indoor air tests to ensure any subsequent vapor mitigation system installed is working properly and report the results to DENR.
- The annual owner certification must state that the vapor mitigation system has been inspected on some schedule approved by DENR and is working properly and report the periodic indoor air sample results.
- The structure shall not be used for any purpose if mitigation systems are not installed or found not to work.
- Additional restrictions as appropriate from previous paragraph.

IV. Testing Requirements:

A. General:

For depth and location of samples and time of year for sample collection, see previous section on Screening Steps.

Summa canisters must be used for all volatile organic compound (VOC) testing. Summa canisters should have pressure gauges. Summa canister and flowmeter can be *either* "100% certified" or "batch certified." Sampler should obtain tubing and connections from laboratory supplying flowmeter and canister. Specify only Swagelok-type fittings or connections with Teflon tape.

A detailed description of sampling equipment and collection procedures must be provided in the work plan. Among other information, a sufficient description of equipment and procedures should be provided to demonstrate no introduction of particulates into the sample canister and to ensure no leaks. Sampler should specify leak check compounds. Best not to use isopropanol. Laboratory-grade helium is generally recommended.

Sampler should record vacuum readings on the canister before and after sample collection. If any problems are encountered, the problem and the solution implemented should be provided in the sample report to the IHSB. In no case should empty or improperly filled canisters be submitted for laboratory analysis.

VOCs should be analyzed by TO-15. The sampler should direct the laboratory to test for the contaminants present in groundwater/soil at the site and their transformation products. TO-15 SIM should be used if the TO-15 detection limits are not lower than the ***Acceptable Indoor Air Concentrations*** (for indoor air and crawlspace samples) or the ***Acceptable Soil Gas Concentrations*** (for soil gas samples) for

the chemicals of concern on the IHSB vapor intrusion tables. TO-15 is preferred over TO-14A as it has a more extensive list of VOCs and because it specifies analysis by GC/MS, providing more defensible data. For semivolatile compounds of concern, additional sample containers/analytical methods will be required. The laboratory conducting the analyses should have National Environmental Laboratory Accreditation Program (NELAP) certification and be qualified to conduct air testing. Field analysis shall only be accepted when the mobile laboratory is certified to conduct the analyses and the contractor demonstrates the laboratory technicians are qualified to perform the analyses. The remediator should contact qualified laboratories prior to submitting samples to verify that the laboratory will be able to achieve detection limits at or below IHSB gas/air targets. The remediator should discuss any modifications needed to achieve such targets.

While soil gas, crawlspace air or indoor air samples should only be tested for contaminants of concern and transformation products, the laboratory may report results for other contaminants. Non-site related contaminants are routinely detected from household sources such as paints, furniture, carpets, cleaning agents and other chemicals used or stored in the home. Only those attributable to the site need to be evaluated for risk. However, the IHSB toxicologist may provide additional information on the risk posed by non-site related contaminants to the homeowner as a courtesy.

At least one duplicate and one trip blank per sample event should be collected. If reusing tubing, must collect an equipment blank between samples. However, it is best to dispose of tubing between samples. Use inert tubing such as nylon. All other equipment must be decontaminated.

The laboratory must also provide method blank and laboratory control sample data.

Data from flux chambers will only be considered "qualitative" data and not "quantitative" at this time. Flux chambers have not undergone sufficient field validation.

Allow no use of exhaust fans, clothes dryers, fireplaces and other items that may induce short term pressure changes during subslab, crawlspace or indoor air sampling. HVAC units should be allowed to run normally.

B. Deep Soil Gas and Subslab Shallow Soil Gas Testing:

Basement subslab samples need to be augmented with samples through basement walls.

Sampling plan should specify how soil gas sampling equipment for deep soil gas will be installed to prevent introduction of air from the surface or near surface. The sampling equipment must be sealed at the surface. Tracer gases should be used to ensure no significant leakage at probe seal (for example >20% tracer, data is unreliable). Sampling plan should specify sample collection rate. Rapid collection could create short circuiting of air from the surface or other non-intended areas. <200ml/min is generally recommended.

Refer to Appendix D, sections D.4.1-D.4.8 of "Vapor Intrusion Pathway: A Practical Guideline," January 2007, ITRC (or most current version) for additional information regarding gas probe installation and leak testing.

The 1 liter summa canisters (smaller size) are preferred for soil gas testing. Larger draws may induce air flow from clean areas or the surface.

If sample collection efforts fail to yield soil gas due to tightness of the soil, another attempt should be made in the general area or the remediating party will need to proceed to the crawlspace/subslab testing phase. For vacant lots, additional testing efforts should be made to collect soil gas.

C. Crawlspace and Indoor Air Testing:

A 2-hour minimum sample run is required. Longer samples are preferred. However the equipment must be under continuous supervision by the consultant performing the test or under secured access (building vacant and locked).

Houses/crawlspaces should be surveyed for background sources and such sources must be removed where possible prior to sample collection. Any sources of contamination that can not be removed should be noted. For example, new furniture/carpet, household cleaning products, glue guns, scented candles, air fresheners, hair spray, new plastic materials or plastic wrapping and dry-cleaned clothes among other items are background vapor sources. For indoor air testing, the house should be well ventilated to remove the vapors from the background sources once these items have bee removed from the structure. Windows should then remain closed 12-24 hours prior to indoor air sampling.

For residential structures: Multiple indoor air samples should be collected from different locations in each house. At least one sample in each house should be collected on the first floor and where the most utility wall/floor penetrations exist (conduits for air flow). If the structure is a more than one story, a sample should be collected from each story. If the structure is a multi-story high rise, then a representative number of samples will need to be collected with attention paid to elevator shafts and other conduits for air flow.

For industrial/commercial structures: Multiple indoor air samples should be collected ensuring to collect from a variety of use spaces (factory floor, office, cafeteria, e.g.) and be collected at suspect points of flow/entry such as elevator shafts, utility wall/floor penetrations, floor drains, concrete control jointing in the floor, and cracks in floor or foundation.

Screening with a PID or FID is recommended to locate points of vapor entry and also background sources. Any areas with elevated readings not attributed to a background source (recently painted object, e.g.) should be included as a sample point. Background sources should be removed where possible.

V. Additional References:

Several states have guidance documents that provide details on sample procedures. These can be used to supplement, but not in place of, the requirements outlined in this guidance document.

California's guidance for probe installation techniques:
http://www.dtsc.ca.gov/lawsregspolicies/policies/sitecleanup/upload/SMBR_adv_activesoilgasinvst.pdf

New York's vapor intrusion guidance:
http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/

ITRC's guidance:
http://www.itrcweb.org/guidancedocument.asp?TID=49