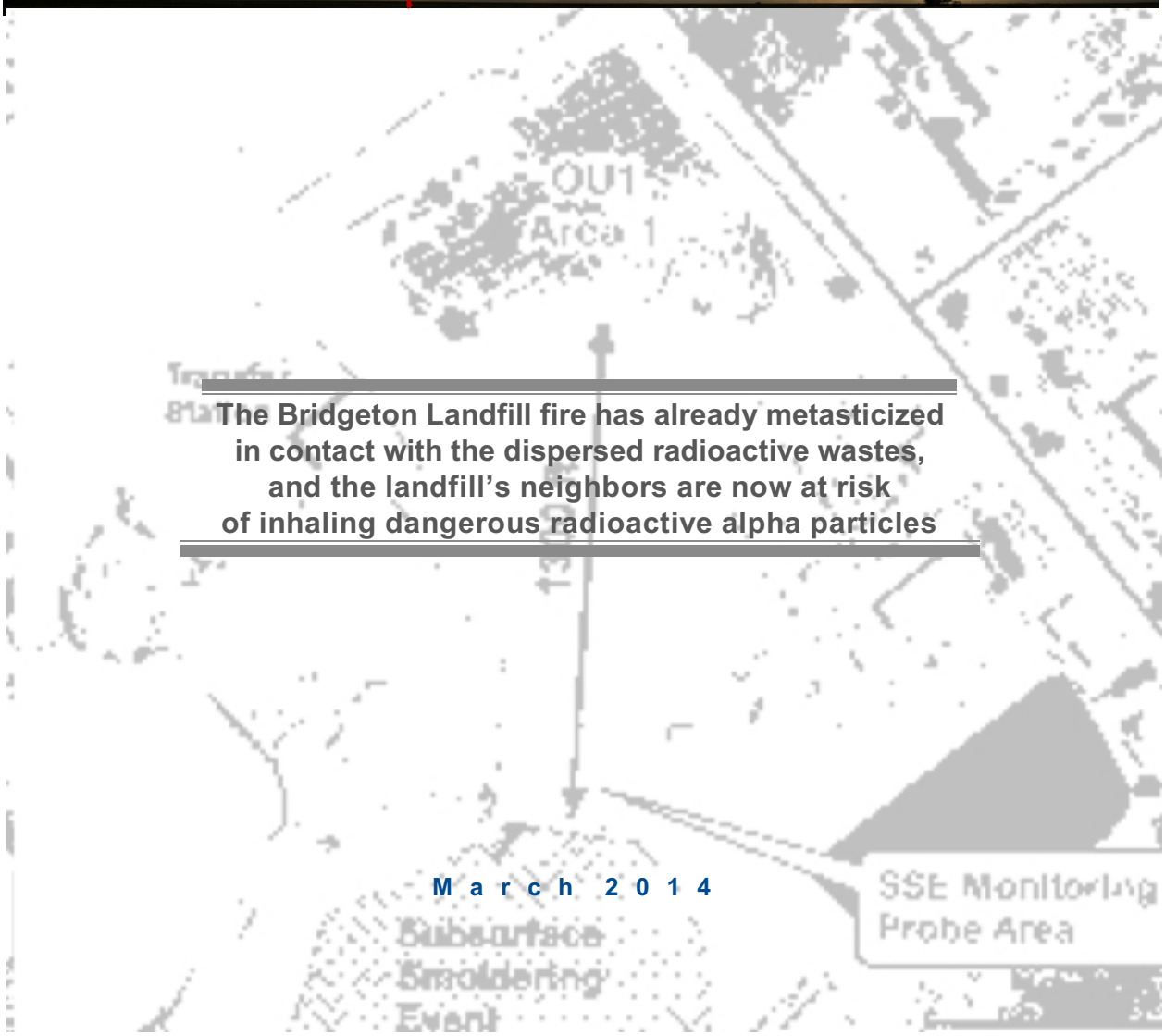
The West Lake-Bridgeton Landfill Fire

a Perfect Storm



The Bridgeton Landfill fire has already metasticized in contact with the dispersed radioactive wastes, and the landfill's neighbors are now at risk of inhaling dangerous radioactive alpha particles

March 2014

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ACRONYMS

ATSDR	Agency for Toxic Substances Disease Registry
CERCLA	Comprehensive Environmental Response Comprehensive Liability Act
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
GEW	Gas extraction well
GIW	Gas Injection well
K	Chemical abbreviation for potassium
LCS	Leachate collection system
MCL	Maximum contaminant level
MDNR	Missouri Department of Natural Resources
OU-1	Operating Unit-1
pCi/l	Picocuries per liter
ppm	parts per million
ppb	parts per billion
PRP	Potentially responsible party (to CERCLA action)
Ra	Chemical abbreviation for radium
RIM	Radiologically impacted materials (the section within Area 1 where the radioactive wastes from Latty Avenue were originally buried)
ROD	Record of Decision
Th	Chemical abbreviation for thorium
VOC	Volatile organic compounds

ACKNOWLEDGMENTS

We would like to express our deep appreciation to Julia Katich, Custodian of Records, and to Brenda Ardrey, Operations Section Chief, of the Missouri Department of Natural Resources, who courteously responded to every Sunshine request for data, and made it possible for the public to become more informed about the disturbing events occurring at the West Lake/Bridgeton Landfill.

Also, we greatly appreciate the assistance of Prof. Robert Criss in interpreting some of the radiation data for us, as well as for his 2013 report, *Risk and Character of Radioactive Waste at the West Lake Landfill, Bridgeton, Missouri*, which informs the groundwater references in this paper. Also, Dr. Vyto Babrauskas provided key insights about the morphology of the Bridgeton fire. Similar, we are indebted to the advice of Robert Alverez, Lucas Hixon and Dan Hirsch on several matters bearing on the behavior of radium and thorium isotopes at West Lake Landfill.

Peter Anderson

EXECUTIVE SUMMARY

Since 2010, an uncontrolled subsurface fire advancing from the south end of the deep Bridgeton Landfill has created a crisis in north St. Louis. In 1973, radioactive wastes had been haphazardly dumped unconfined on a shallow shelf at the northmost edge of the landfill, called "Area 1." Were the radionuclides and fire to intersect, many fear that the intense heat of the fire would release dangerous levels of radioactivity into the air over the heavily populated surrounding area.

Repairs being made to Bridgeton Landfill

Republic Services, the landfill owner, has claimed that there is no risk of the fire reaching the radioactive wastes because the two are 1,300 feet apart. The company also claims that, even if the fire did reach the radiotoxins, nothing untoward would ensue.

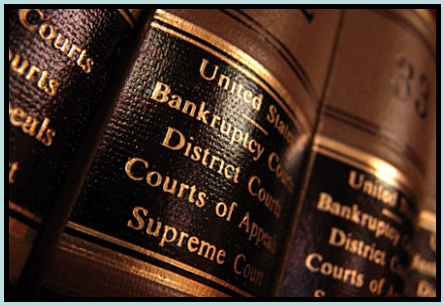
This report analyzes the existing field data, most of which was compiled by Republic itself, to independently evaluate the company's the 1300-feet-of-separation claim and the further claim that the interaction of the fire and radiotoxins would have negligible consequences for the people who live in the vicinity. It then proceeds to make recommendations on what should be done in light of the conditions that actually exist. That analysis has found that –

- ***Radwastes spread***. A significant fraction of the radioactive wastes have migrated widely out from Area 1 and around the landfill, if not also beyond.
- ***Radwastes will reach Area 1 soon***. The fire has spread from the South into the North and is mostly likely to reach Area 1 within the next 1½ years.
- ***Radioactivity being released now***. The radiotoxins have been in contact with the intense heat of the fire's core for the past year, and dangerous alpha particles have and continue to be released into the surrounding area, although their impact in cancers and death will be delayed for years by lag effects.
- ***Radioactive releases cannot be managed***. Because the landfill is also unlined and sited in an alluvial flood plain, the existing radiological problems, unlike odors, cannot be managed, and radioactivity will continue to be released at least until the fire burns itself out, which could take 20 more years.
- ***Buried radwastes threaten water supplies***. Also, because of its location in a flood plain, the radioactive wastes that still remain in Area 1, and the much larger contaminated Area 2 nearby, represent a serious risk to the surface and groundwater systems in the area, and EPA has shown itself incapable of acting.
- ***Republic is proceeding too slowly to protect Area 1***. The Attorney General's decision to force Republic to proceed directly to excavate a fire break around Area 1 was sound; but now the company is slow walking the preliminary site characterization studies because it says it was surprised to fine the path of the planned barrier contaminated with radioactivity.

For these reasons, the report makes the following recommendations –

- ***Action to complete fire break***. The Attorney General should assess whether the Army Corps of Engineers' FUSRAP program can complete the isolation barrier around the radioactive wastes that remain in Area 1 before the fire reaches it, and otherwise seek to convince EPA to order Republic to complete the barrier in time, in order to prevent the ongoing disaster from becoming a catastrophe.
- ***Remaining radwastes should be exhumed***. The radioactive wastes that still remain in Areas 1 and 2 represent a serious risk to the local air shed and to surface and groundwater: responsibility should be given to FUSRAP to exhume them to an appropriately sited and licensed facility.
- ***Relocation assistance offered***. Those living directly downwind of the landfill are being subjected to the continuing risk of exposure to dangerous alpha emitters and Republic should be ordered to offer them relocation assistance.
- ***Insuring Republic, not taxpayers, pay***. Because most of the crisis is due to the fire that was caused by Republic's gross negligence, care should be taken that the company, and not the taxpayer, is assessed for all of those costs.

Bridgeton mother and son landfill neighbors



In the events leading up to the crisis at the West Lake-Bridgeton Landfill today, everything conceivable – and inconceivable – that could go wrong did go wrong, and, in the very worst way. That underlies the reason why only limited remedies are available now.

Looking to the future, Republic's goal of "positive isolation and containment" is no longer possible. The ongoing release of dangerous radioactivity into the atmosphere will continue spreading alpha emitters across the area until the fire burns itself out, which could take as much as 20 years. The enhanced cover will only (imperfectly) address odor issues, and time may have already run out on installation of an isolation barrier to prevent the fire from reaching the radioactive wastes that still remain where they were buried.

The other shoe that will soon fall lies beneath the ground. Equally uncontrollable releases of radioactivity into the groundwater will continue for the foreseeable future. Those releases, which are out of sight, may seem to be moving at a slower rate that the atmospheric emissions. But, the area's alluvial deposits are porous, groundwater flows at about 750 feet per day, and the next major flood that tops or undermines the levies, leaving the radioactive landfill under several feet of water, is also only a matter of time.

The events leading to the Bridgeton Landfill fire have created a perfect storm. ➠

INTRODUCTION

In a landfill, as in a coal mine, underground fires are a cause for serious concern. For they are almost impossible to extinguish, and, uncontrolled, can persist for decades before exhausting all the available fuel. In the process, critical safety systems can be degraded and dangerous byproducts from incomplete combustion, along with noxious odors, can escape into the atmosphere affecting neighbors for several miles downwind from the site.[1]

FIGURE 1 – Map of West Lake/Bridgeton Landfills

The recent subsurface fire in the Bridgeton Landfill, North of St. Louis, first noted in 2010, raises those concerns to an entirely new level. For the landfill is contiguous to illegally dumped radioactive wastes from the WWII atomic bomb Manhattan Project, which is in the northern-most section of the site called "Area 1."

FIGURE 1 shows the Bridgeton Landfill (outlined in black). Also shown are the two areas where the dangerous radionuclides were haphazardly dumped unconfined in 1973, and which together compromise the West Lake Landfill, or Operating Unit 1 (outlined in orange).[2]

The great concern has been how to avoid the fire and the radioactive wastes from coming in contact, which would release dangerous radioactivity into the environment. Contamination of the area around the Bridgeton Landfill by dangerous radioactive isotopes would have especially serious implications because the region in North St. Louis is heavily populated and developed, as indicated by the map of the area in FIGURE 2. The map shows within 5 miles, 3 residential neighborhoods, 10 schools, 11 churches, a hospital complex, the region's international airport and the Missouri River,[3] the source of drinking water for 300,000 people.[4]

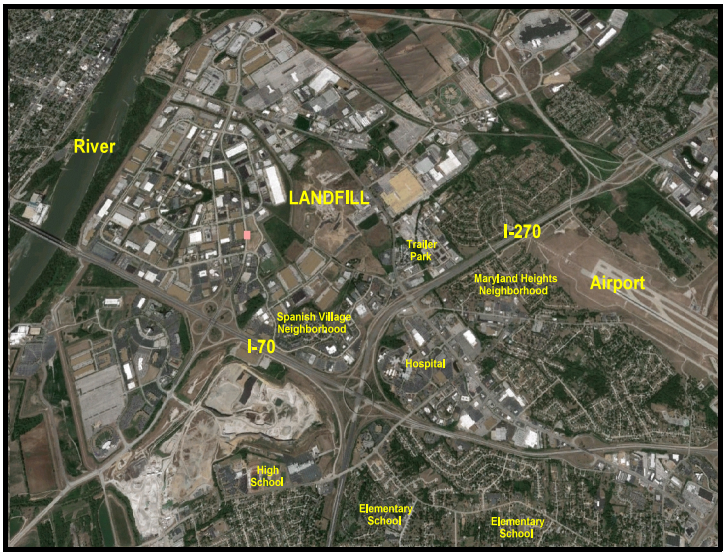


FIGURE 2–Map of North St. Louis Around Bridgeton Landfill

Republic Services, which owns the site, has attempted to calm those concerns, with reference to the map in FIGURE 3. The map's rendering purports to show that the fire is confined to the South Quarry, and the radioactive wastes to Area 1, which are 1,300 feet apart.[5]

FIGURE 3 – Map used to claim 1300 feet distance from fire (in orange) to radioactive wastes (in red)

To that 1,300 feet of separation, the Regional Administrator of the Environmental Protection Agency Region 7 (EPA) has added further assurances "that people are not now exposed to unsafe radiation from the contaminated waste buried in [West Lake] because the site is fenced to prevent public access."[6]

FIGURE 4–Fence around Area 1 at West Lake/Bridgeton Landfill

There are factual shortcomings with these claims, which are intended to provide assurances to the public that there is no risk of the fire reaching the radioactive wastes.

This report evaluates whether and the extent to which the Bridgeton fire has come into contact with the migrating West Lake radioactive wastes, the consequences and the needed remedies.

THE RADIOACTIVE WASTES HAVE MIGRATED THROUGHOUT THE BRIDGETON LANDFILL

Because the radioactive wasted dumped in Area 1 are unconfined, the question of whether they remain there, or have migrated out into the unlined landfill turns on the hydrogeologic setting.

■The hydrological setting of the unlined landfill is in an alluvial flood plain

To recapitulate the hydrogeologic background from the *Criss Report*,[7] the Bridgeton Landfill is located in the Missouri River flood plain, underlain by alluvial aquifer and fractured limestone, with a high and fluctuating groundwater table that varies 10 to 40 feet and leaves behind perched pools of water. Groundwater moves rapidly in the direction toward or away from the river depending upon the river stage and precipitation.[8]

Also, there is an additional significant influence on groundwater flows around the two quarries of the Bridgeton Landfill, which later takes on further import regarding the extent the radioactive wastes have dispersed.

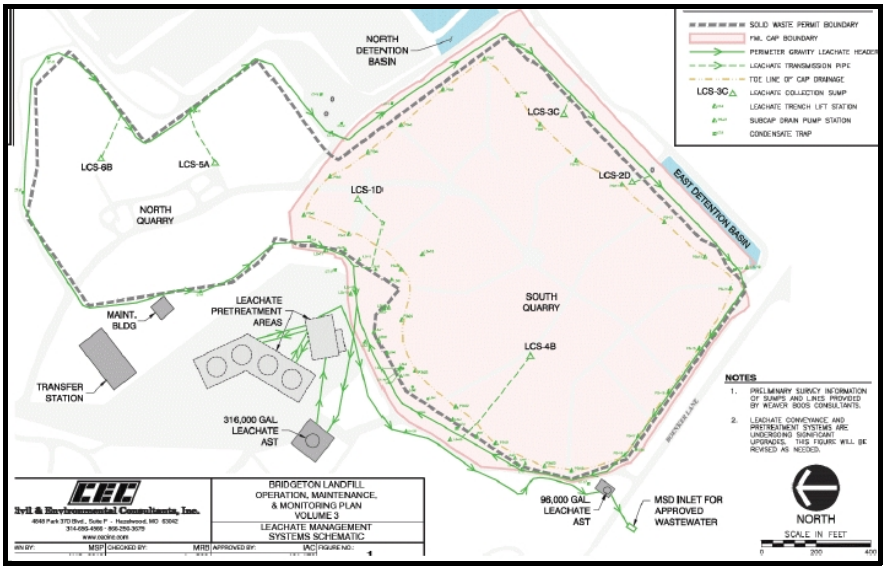


FIGURE 5–Location of original sumps pumps in Bridgeton Landfill [NOTE: North to left]

Rules require a landfill to be lined, have 5 feet of separation with the high water table and be outside of the flood plain.[9] In order to secure a permit to operate this landfill in 1995 in the flood plain, amidst the water table and without the required liners, the company installed pumps towards the middle of each quarry, as shown in FIGURE 5. These were intended to create an inward cone of depression amidst the surrounding groundwater flows in an attempt to prevent contaminants flowing outward from the landfill and into drinking water supplies. At the same time, however, these cones of depression also drew groundwater from the periphery to the middle of each quarry, which aggressively spread contamination throughout the site.[10] More recently, those sump pumps have had to be removed to make it possible to install the new plastic sheet, and they are being replaced with new sump pumps arrayed around the periphery of the two quarries approximately 200 feet apart.[11]

Essentially, these vertical and lateral groundwater flows in the landfill, continually flush the landfill, including Area 1, where one of the perched pools has been located.[12] The map in FIGURE 6 represents one effort to describe the direction of groundwater movement during one groundwater sampling. Groundwater movement is shown as moving from the perimeter of the quarries to the center where the sump pumps were located. [13]

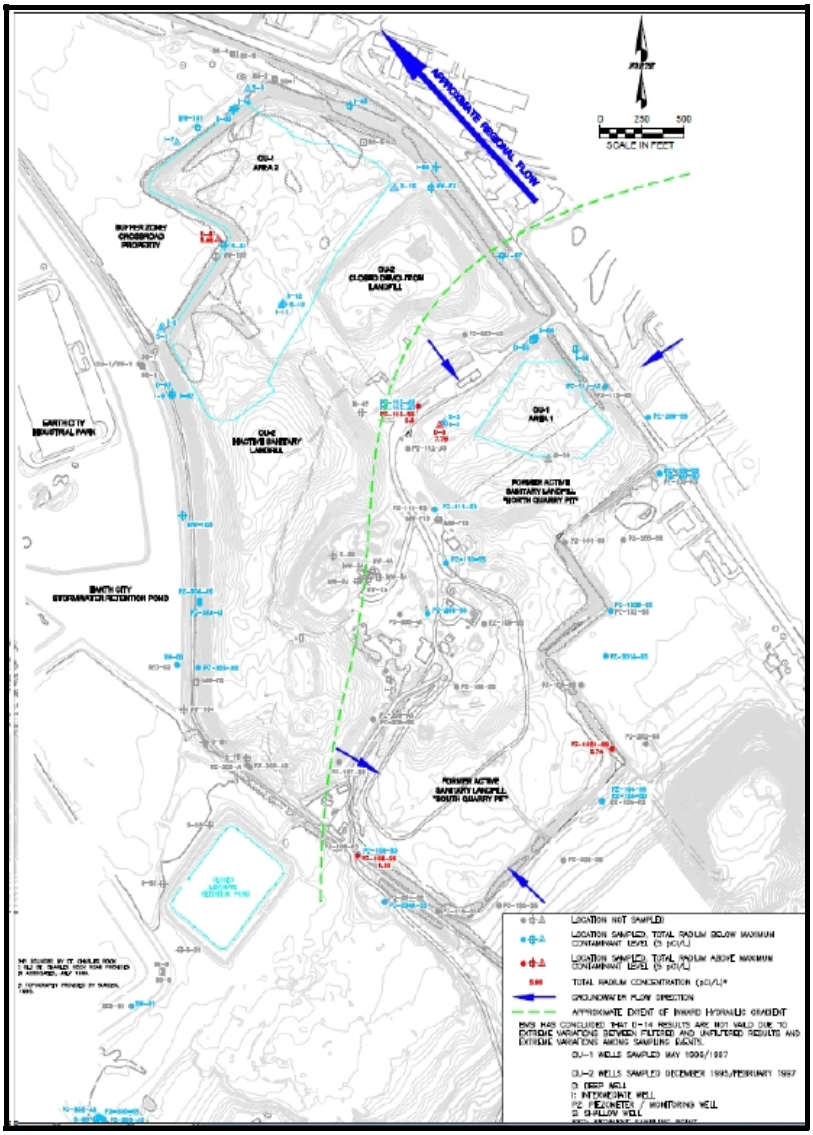


FIGURE 6– Map showing direction of groundwater flows from the influence of the sump pumps

With no engineered or natural barriers, the radioactive wastes that were buried loose in Area 1, in the form of fine particles the consistency of talcum powder, have been left free to migrate over the past 40 years. "Any percolating waters," Dr. Criss concluded, "can encounter radwaste and then move laterally and downward into the alluvial aquifer, or into the bedrock aquifer in the subjacent Mississippian limestone."[14]

■The radioactive wastes buried in Area 1 are dangerous

EPA has continued to repeat anecdotal reports that the radioactive wastes that were haphazardly dumped in Area 1 were relatively benign leached barium sulfate residues.[15]

However, careful forensic investigation by Robert Alverez later established that the wastes are much more dangerous residues of radium-226 and 228, and thorium-230 and 232 isotopes, whose serious health risks are described later on page 37, along with soils contaminated with radioactive isotopes.[16] Other anecdotal reports variously describe the form that these residues took as either like talcum power or slime.

■Republic's groundwater testing shows the radioactive wastes migrating throughout the landfill

A close examination of the groundwater monitoring records from Republic in 1996, 2004, 2012 and 2013 shows there were high levels of radioactivity dispersed throughout the landfill, which did not became most pronounced until the past two years.[17]

FIGURE 7 shows the location of the functioning groundwater wells around the Bridgeton Landfill in 2013, with the readings for Total Radium 226/228 in pCi/l shown in pink next to each well, and those readings above the MCL are highlighted in green.

TABLE 1 on the following page highlights in tabular form the reported levels of radioactivity (in picocuries per liter) in excess of background levels (≈2 pCi/l)[18] since 1996, with the wells showing exceedances in any test rearranged in order to be grouped by their location in the landfill (see the NOTE for an explanation of the abbreviations). The values are shaded from light (lowest) to dark blue (highest) in order to highlight the wells with the greatest reported levels.[19]

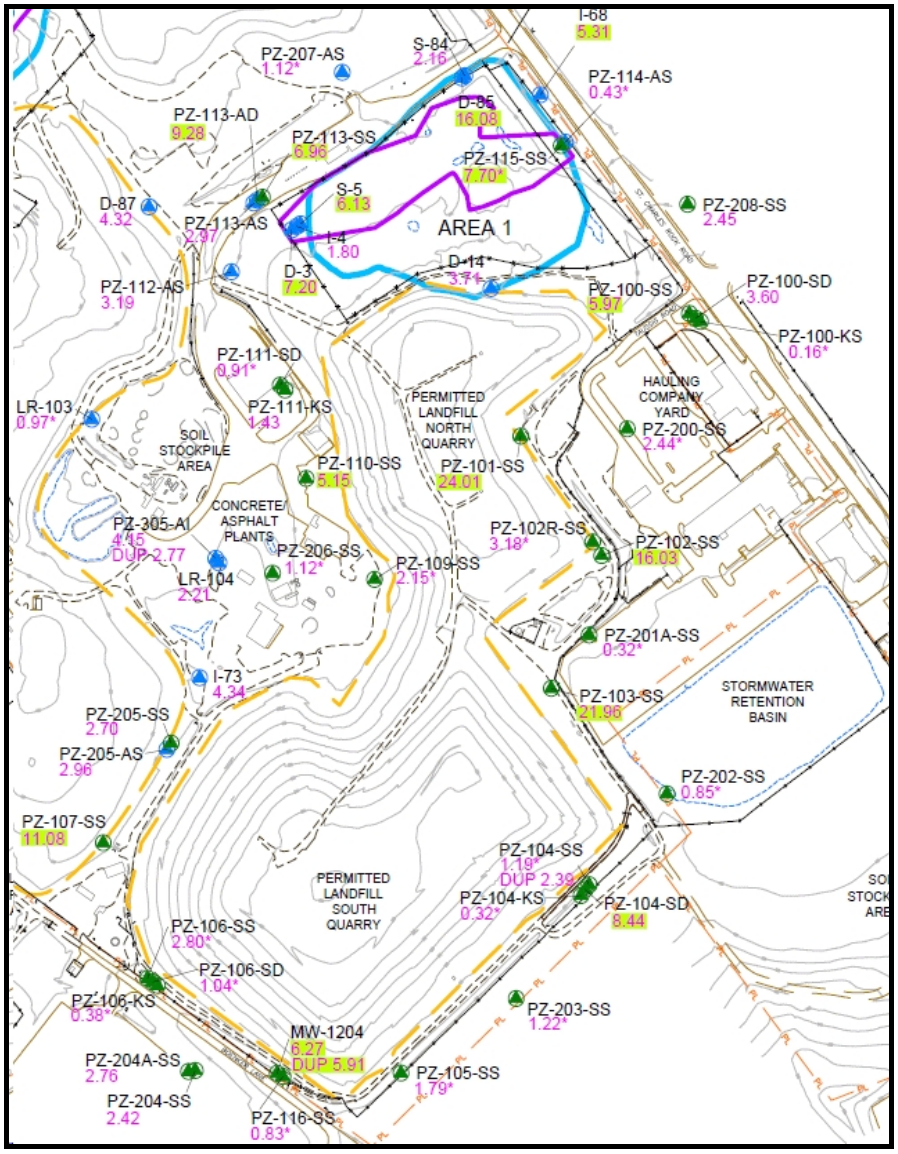


FIGURE 7 – Map of groundwater wells around Bridgeton Landfill in 2013

WEST LAKE/BRIDGETON LANDFILLS
RADIUM EXCEEDANCES IN GROUNDWATER WELLS
(Ordered by Location)

	Well	Location	Total Ra-0226/228 in Grndwtr>2pCi/L 2013	2012	2004	1996/1997
RIM	D 85	***ATC***	16.08	13.79	<5	<5
	D 3	***AMC***	7.20	10.22	7.75	7.50
	PZ 115 SS	***AMC***	7.70	6.20	-	-
	S 5	***AML***	6.13	0.67	<5	NT
AREA 1	S 84	ATC	2.16	3.26	<5	NT
	PZ 113 SS	ATL	6.96	1.91	5.80	5.80
	I 68	ATR	5.31	4.72	<5	<5
	PZ 112 AS	AML	3.19	5.82	-	-
	PZ 113 AD	AML	9.28	11.12	<5	NT
	PZ 113 AS	AML	2.97	0.84	-	NT
	PZ 208 SS	AMR	2.45	0.83	-	-
	D 14	ABC	3.74	5.17	-	-
NORTH QUARRY	PZ 100 SD	NTR	3.60	2.74	-	NT
	PZ 100 SS	NTR	5.97	4.23	-	<5
	PZ 101 SS	NMR	24.01	16.19	-	-
	PZ 200 SS	NMR	2.44	7.74	-	-
	PZ 202 SS	NMR	0.85	4.58	-	-
	PZ 110 SS	NBL	5.15	6.59	-	<5
	PZ 102 SS	NBR	16.03	9.38	-	<5
	PZ 102R SS	NBR	3.18	4.52	-	<5
NECK	PZ 109 SS	KML	2.15	5.30		NT
SOUTH QUARRY	I 73	STL	4.34	0.96	-	-
	PZ 103 SS	STR	21.96	6.06	-	NT
	PZ 107 SS	SML	11.08	8.95	-	NT
	PZ 205 SS	SML	2.70	1.73	-	-
	PZ 104 SD	SMR	8.44	3.09	-	<5
	PZ 104 SS	SMR	1.19	3.09	-	-
	PZ 106 SS	SBL	1.04	5.22	6.33	
	PZ 1201 SS	SMR	-	-	-	5.74
	PZ 204 SS	SBL	2.42	1.10	-	-
	PZ 204A SS	SBL	2.76	2.34	-	-
	MW 1204	SBC	8.27	6.68	-	-
	PZ 106 SS	SBR	2.80	5.20	-	6.33

TABLE 1

Next in FIGURE 8 is a geographic representation of the data in TABLE 1, using the same blue shaded color coding to indicate levels of radioactivity at each well with exceedances in 2013.

FIGURE 8 – Map of groundwater well locations showing exceedances for radioactivity

Three observations follow from this last FIGURE. First, this data draws a compelling case of widespread dispersal of the radioactive wastes that had been dumped in Area 1 over 40 years ago. As examples, in 2013 Republic's data shows 30 readings above background, which is 2 pCi/l.[20] Also, 15 readings were above the maximum contaminant level (MCL), which is 5 pCi/l.[21] Thus, from among the 49 total number wells in the immediate vicinity of the two Bridgeton quarries, 61% of those wells exceeded background, and 31% were also greater than MCLs.

Second, although the data is limited, that which does exist suggests, but does not establish, that there has been a marked increase in the dispersal of radioactivity over time, concentrated in the last two years. There were, for example, 26 more readings over background levels than in 1996, and 31% of them were also greater than MCLs. In 1996, 36% of the readings of interest were over background, but in 2013, 91% were. Also, the reported peak readings increased over time. In 1996, the highest of these readings outside of Area 1 was 7.5 pCi/l; in 2004, that was 7.75 pCi/l; in 2012, 16.9 pCi/l; and in 2013, 24.01 pCi/l, or 220% greater than in 1996. Similar, a comparison of readings in Area 1 found significantly elevated readings in 2013 where there had been no readings in 2000.[22] However, over the 16 years that groundwater tests have been run, the number of wells also increased in 2013 to 49 wells from 20 in 1996.

Third, of possibly even greater concern, the highest levels of radioactivity in the groundwater wells reported by Republic were neither in Area 1, nor in the smaller, and supposedly much more radioactive part of Area 1, called the Radiologically Impacted Materials section (RIM) (see the purple shaded area inside Area 1 in FIGURE 1 on page 1). In fact, reported levels of radioactivity were 50% greater in Groundwater Well No. PZ-101-SS, which is in the middle of the North Quarry, than in the RIM, and 37% greater in Well No. PZ-103-SS, which is in the middle of the South Quarry about 1,300 feet from Area 1. See TABLE 1.

One disturbing interpretation from this anomalous finding – in which the reported radioactivity is greater further from the place where it was originally dumped – is that today there could be greater concentrations of radioisotopes spread out across the landfill than remain in Area 1. But, to be clear, while the reports demonstrate extensive dispersion of the radionuclides, there is no data with which to reliably estimate the actual proportion of the original radioactive wastes that has migrated since that time beyond the RIM section.

Further confirming the conclusion that the radioisotopes have migrated from the RIM section is Republic's gamma cone penetration tests during December 2013 between the RIM section and the North Quarry that found significantly elevated readings possibly as high as 390 pCi/.[23] For, if the radioactive wastes have migrated out of the RIM into the rest of Area 1, Republic's earlier claim that those wastes are immobile is, by their own subsequent finding, no longer operative.

Unfortunately, Republic's response to the groundwater data seems to reflect an unwavering determination to deny the overwhelming force of factual evidence, rather than to provide a reasoned reply or plan to reduce the uncertainty around the samples.

Any readings that suggest normal reading are accepted unquestioningly: any data that indicates otherwise is rejected and sent back for re-analysis or re-interpretation. Earlier EPA Region 7 had also been evasive, but, of late, even EPA appears to be reevaluating the situation.

Initially, EPA Region 7 dismissed warnings in the first 1996 groundwater samples. The agency argued that the radioactive wastes could not migrate outside of Area 1, because "[t]he lack of radionuclide contamination in groundwater at the Site is consistent with the relatively low solubility of most radionuclides in water and their affinity to adsorb onto the soil matrix."[24]

To be clear, however, "solubility" does not, as might be thought, imply a binary process in which particles either do or do not become completely dissolved in a solvent, as if there are some materials that dissolve – and which can disperse – and all the others that do not – and therefore remain fixed. Rather, solubility is a continuum at one end of which some particles remain suspended while, at the other end, they break down into sub-microscopic sizes and more readily disperse throughout the medium.[25]

To better reflect the continuum in the real world, the better term is colloidal transport. Radium and even less so, thorium, may not exhibit as much solubility as salt in water, but that does not lock them in Area 1 forever. In the unique conditions of a high and fluctuating water table in the Missouri River flood plain with porous alluvial deposits, they will become mobile albeit at a slower rate.

Low solubility only suggests that the particle's colloidal transport will tend to be slower. But, amidst porous alluvial deposits in a flood plain, 40 years offers a long time for such a particle to migrate, as these groundwater readings attest to. Also, reactants and solvents, which are also reported to have been dumped at West Lake,[26] have been shown to reduce absorption by radium and thorium in the soil that otherwise would reduce mobility.[27]

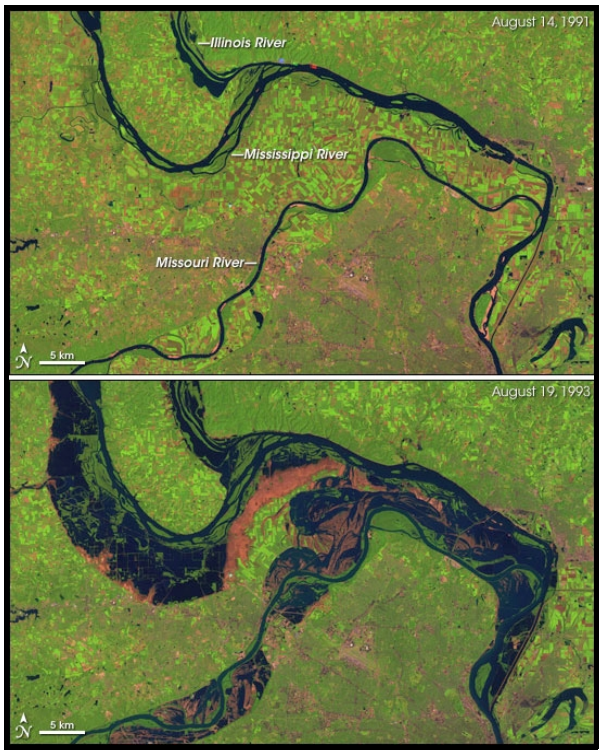


FIGURE 9– Before and After Map of 1993 Flooding of Missouri River Around North St. Louis

Photo Credit: NASA

Region 7 also dismissed the early groundwater results, which then only indicated small exceedances in a few wells, because they were "not indicative of on-site contaminant plumes, radial migration, or other forms of contiguous groundwater contamination."[28]

However, for one thing, there were too few wells monitored around the North and South Quarries in 1996 and 2004 to discern plums. More important, plumes of radionuclides emanating from the RIM area would, over four decades, be very significantly disrupted by, first, the movement of the water table that fluctuates vertically 10 to 40 feet in a year, as well as, second, the manmade lateral movements created by the landfill's sump pumps, previously described on page 4, not to mention, third, major flooding events such as those in 1993 and 2011 that saturated the ground, even if in those cases the levees held back the surface water from Bridgeton. See FIGURE 9 for aerial photograph of the flood plain in the 1993 flood.[29]

Therefore, any original plumes would have been disrupted by those vertical and horizontal hydraulic flows a long time ago, and one should no longer necessarily expect to see a dispersion of exceedances suggesting plumes of contaminants.

Noteworthy, after the growing extent of dispersion shown by the 2012 groundwater report, EPA Region 7, which hithertofore has not acknowledged that there was any cause for concern over the elevated radiation readings outside of Area 1, modified its views. Now, instead of denial, its position is agnostic:

> "EPA assesses the 2012 groundwater data as not proving or disproving the existence of a groundwater contaminant plume at the site. For this reason, EPA has requested that the potentially responsible parties (PRPs) conduct three additional rounds of groundwater sampling in 2013."[30]

Republic, on the other hand, continues to characterize the extremely high readings as the background radiation that existed in the area before the radioactive wastes were dumped at West Lake.[31]

But, background levels of radioactivity in the area were carefully established by Region 7 in its 2008 Record of Decision as approximately 2 pCi/l.[32] In the last two years, which is four years since that determination, the reported peak levels are now recurringly in excess of 10 and 20 pCi/l – or up to more than ten times greater. When Republic seeks to characterize as naturally occurring readings that a magnitude greater than established background levels, the company strains credulity.

THE SUBSURFACE FIRE HAS ADVANCED FROM THE SOUTH QUARRY INTO THE NORTH QUARRY AND IS ADVANCING ON AREA 1

Fire in proximity to radioactive wastes is a great concern because intense heat can cause the buried isotopes to volatize, or transition into their gaseous state, and, with the inevitable fissures in the overburden and cracks in the covers, escape into the atmosphere. When the radioactive wastes have migrated throughout the landfill into the sections where the fire rages sufficiently hot to potentially volatize radioisotopes, that is presently a great ongoing concern. If the fire proceeds further and advances into Area 1 where those wastes were originally dumped, then that is an imminent catastrophe.

■ The radioactive wastes have migrated to where the fire is sufficiently hot to volatize the radiotoxins

The previous section established that the radioactive wastes have widely dispersed throughout much of the landfill, and extend to the area in the South Quarry where elevated temperatures from the fire are the hottest, as well as in the North Quarry where they are, in places, elevated, though, at present, not nearly as much as in the South. The next question is whether those temperatures in the South Quarry are hot enough to volatize the radioisotopes.

Three sets of instruments provide a very limited indication of temperatures inside the Bridgeton Landfill. First, there are gas extraction wells (GEW), which are installed to collect and combust landfill gas, and also contain instruments in the headers to measure the temperature of the gas collected in that well.

Second, as part of the several remedial efforts at Bridgeton, there are gas interceptor wells (GIW), which were installed by April of this year in the neck between the quarries in an effort to draw off the heat from the fire advancing out of the South Quarry and retard its proceeding into the North Quarry. These also have instruments to measure the temperature of the captured gases.

Third, there is another set of wells specifically installed to measure temperatures (TMP) with thermocouples through the entire span of the well in 20 feet increments. Unfortunately, they continue to suffer failures, and, in any case, are unfortunately only located in the narrow neck.[33]

There are a number of problems with each type of well for measuring temperatures, because there is no good instrumentation inside a landfill that can accurately record temperatures, especially for very high temperatures.

In addition to those generic constraints, while the TMP wells install thermocouples for every 20 feet of the 200-300 foot depth, the GEWs and GIWs report an average temperature for the entire well, even though the fires typically only inhabit the area around a small extent of the pipe. By averaging the parts of the well's span where the fire both is and is not located, the reported average values are lower than the actual temperature of the fire itself.[34] FIGURE 10 shows the location of the wells.

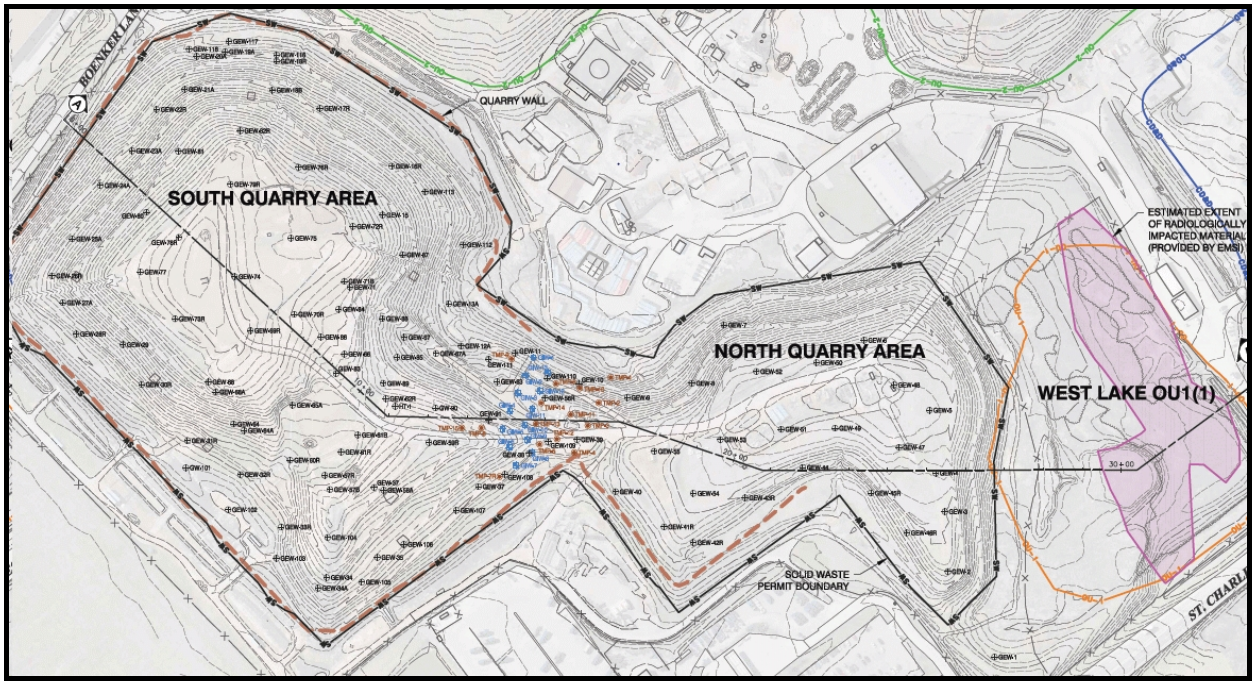


FIGURE 10 – Map of locations of gas wells inside Bridgeton Landfill in 2013 [NOTE: North to right]

TABLE 2 shows the temperatures reported in the peak month for each of these wells with reported temperatures of 150°F or greater since September 2012.[35] Temperatures for GEWs and GIWs have been normalized by 10% to attempt to correct for the averaging effect, based upon a comparison of adjacent GEW and TMP wells in the Bridgeton Landfill.

WEST LAKE/BRIDGETON LANDFILLS
PEAK TEMPERATURES REPORTED IN GAS WELLS
(ordered from hottest to coolest among wells > 150 degrees F)
9/2012 - 10/2013

TMP-8	309	GEW-57B	230	GEW-56R	189
TMP-7	272	GEW-65A	230	GEW-54	188
TMP-9	254	GEW-72R	230	GEW-78R	188
GEW-111	252	GIW-09	230	GEW-106	186
GEW-34	249	GIW-07	227	GEW-21A	185
GEW-33R	248	GIW-10	227	GEW-20A	184
GEW-32R	244	GEW-11	226	GEW-25A	184
GEW-66	242	GIW-02	226	GIW-12	180
GEW-76R	242	GEW-27A	225	TMP-10	180
GEW-90	242	GEW-14A	224	GIW-11	179
GEW-109	241	GEW-62R	223	TMP-5	178
GEW-35	240	GEW-79R	220	TMP-14	177
GEW-57R	240	GEW-18R	218	GEW-23A	175
GEW-59R	240	GEW-31R	218	GEW-43R	174
GEW-60R	240	GEW-36	218	GEW-77	174
GEW-63	240	GEW-82R	218	TMP-2	174
GEW-64	240	GIW-06	215	GEW-29	171
GEW-70R	240	GEW-18B	213	TMP-6	170
GEW-74	240	GIW-03	211	GEW-03	169
GEW-91	240	GEW-30R	208	GEW-55	169
GIW-01	240	GEW-40	208	GEW-73R	169
GEW-75	238	GEW-12A	206	GEW-81	169
GEW-110	238	GEW-17R	206	GIW-08	169
GEW-13	237	GIW-13	201	TMP-11	169
GEW-37	237	GEW-16R	197	GEW-24A	167
GEW-85	237	GEW-19A	196	GEW-53	167
GEW-58	236	GEW-38	194	GEW-80	167
GEW-69R	236	GIW-04	194	TMP-12	159
GEW-71	236	GEW-15	191	TMP-3	158
GEW-26R	235	GEW-28R	190	TMP-1	150
GIW-05	234	TMP-13	190		

TABLE 2

TABLE 2 shows the temperatures reported in the peak month for each of these wells with reported temperatures of 150°F or greater since September 2012.[36] Temperatures for GEWs and GIWs have been normalized by 10% to attempt to correct for the averaging effect, based upon a comparison of adjacent GEW and TMP wells in the Bridgeton Landfill.

In generic discussions, the temperature thresholds of initial concern are set at 131°F and of heightened concern at 175°F. Those thresholds assume that the landfill is at a point in its life where it is actively generating gas, from which heat is a byproduct of decomposition, typically ≈130°F.[37] But, the Bridgeton Landfill shut down in 2004, after which it stopped receiving new organic discards needed to keep rejuvenating the process of decay, which otherwise slows down over time. FIGURE 11 shows something how the rate of gas generation has probably slowed at Bridgeton since 2004.[38] For these reasons, the threshold of heightened concern that a fire exists specific to Bridgeton is better considered to be 150°F. That reflects the same increase over Bridgeton's lower background temperatures as in the general case when 175°F is considered to be of heightened concern.

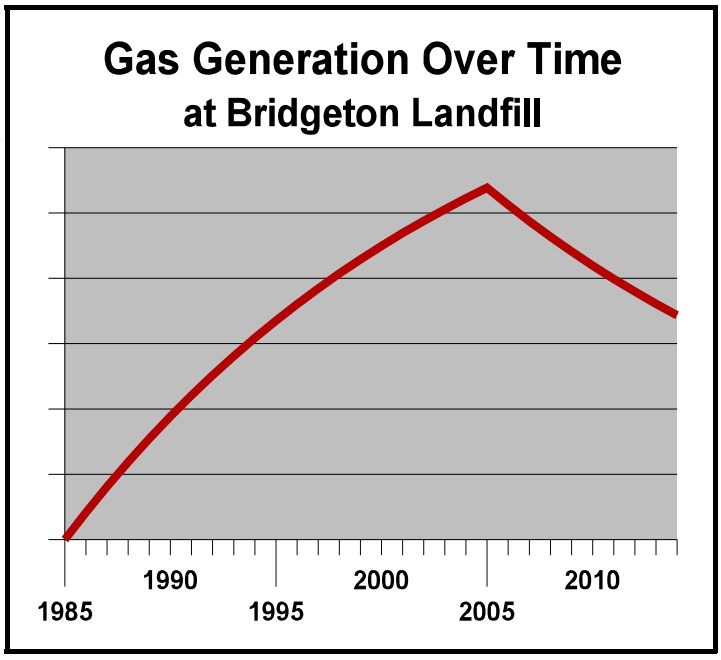


FIGURE 11

There are 92 readings out of 117 wells greater than 150°F, or 79% of that total, of which the highest recorded was 309°F associated with a nearby GIW.

FIGURE 12 shows the location of the gas wells that experienced exceedances, using the same red-to-yellow color coding to indicate the intensity of the heat. The elevated temperatures are concentrated roughly in the center of the South Quarry and slightly to the center and west side of the North Quarry, while the greatest temperatures appear to be in the narrow neck that separates the two quarries, presumably because, as discussed later, the GIWs are pulling excess oxygen from the surface that feeds the fire.

FIGURE 12 – Map of location of gas wells showing elevated temperatures

Note, however, that the preceding TABLE and FIGURE provide some, but only seriously incomplete data on the extent that the temperatures are elevated in the Bridgeton Landfill, which, in fact, is almost certainly substantially hotter in places. For one thing, the instrumentation is not adequate to measure high temperatures.

For another, like in a well-heated wood stove that can put out much more heat with a smoldering "blue" embers when the oxygen intake is closed, landfill fires also usually go pyrolytic,

as well. This is a process of thermo-chemical decomposition of the organic discards in oxygen starved conditions, in which temperatures are significantly greater.[39]

Republic found pyrolytic conditions in the South Quarry that are responsible for the substantial subsidence, though it has not recorded its core temperatures.[40] Laboratory studies supported by field surveys have found that peak temperatures of prolytic underground landfill fires may approach as high as 1,200°F or more.[41] The fact that post-event field surveys of subsurface landfill fires find polyethylene garbage bags depolymerized, which requires temperatures in excess of 700°F, tends to support those laboratory estimates.[42]

The GEW wells that are in the area where the South Quarry fire is hottest and also where pyrolytic conditions are most likely to exist, are typically made of PVC, which begins to melt at 284°F.[43] Therefore, they are useless for informing us of temperatures at the depths where the fire is hottest. Whatever values that those GEWs are providing are from above the depths where the fire is so hot that the well segment has likely been destroyed.

■ The fire in the South Quarry is advancing into the North Quarry to Area 1

The related question is whether there is also an imminent concern that the fire is advancing into the North Quarry and will soon reach Area 1. Republic persists in maintaining that there is no underground fire in the North Quarry.[44] Unfortunately, Republic has provided no facts to support its claim and has refused as yet to either (1) confront elevated temperatures in the southeast section of the quarry, (2) provide other sampling data that could explain the source of the elevated temperatures (3) provide subsidence measurements or (4) install the temperature well instrumentation that would unequivocally establish whether the high temperatures now reported inside and through the neck are already entrenched and expanding in the North Quarry.[45]

However, the data that do es exist establishes that the GIWs have not worked, and that the fire is almost certainly past the northernmost end of the neck. That data also strongly suggests that the fire is now expanding into the North Quarry.

To display visually the critical places in the landfill where temperatures have been high, we overlaid the peak reported temperatures in the TMP and GEW wells in the neck and in the nearby areas of the North Quarry.

Peak temperatures were used because reported temperatures are not absolute conditions out of the control of the operator. Rather, in situ temperatures in a landfill are, to a not inconsiderable extent, under the operators influence, such as a result of how much negative pressure is applied through the gas collection and related extraction wells. This is especially the case when there is no low-permeable cover to prevent oxygen from also being pulled into site from the surface that inflames the fire.

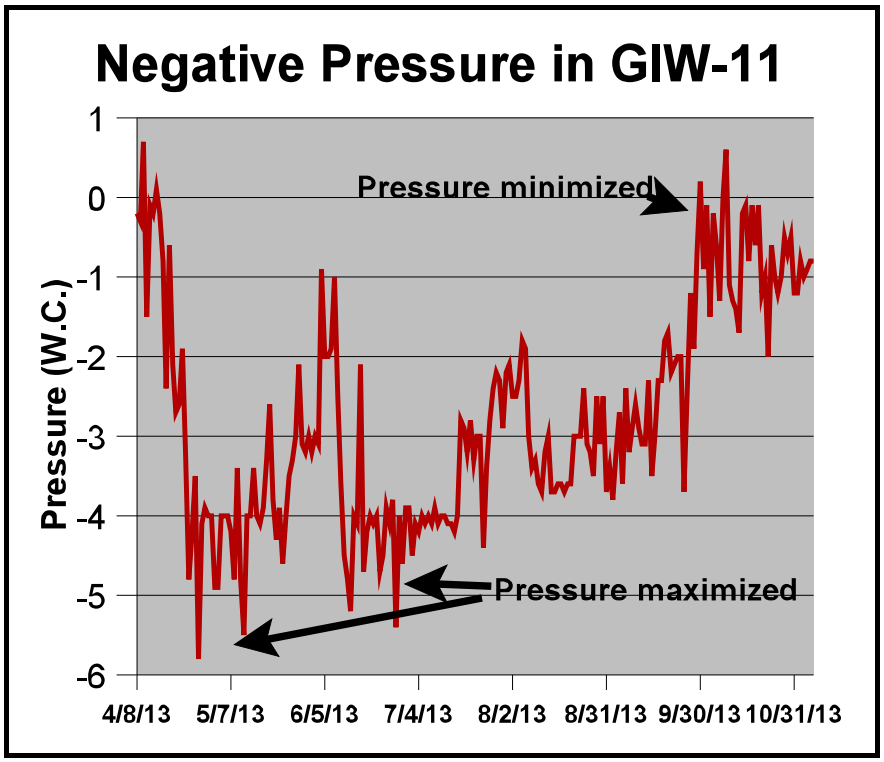


FIGURE 13

FIGURE 13 illustrates this with the negative pressure readings applied in GIW-11 over time, which shows that heavy vacuum force was applied in May and then again in the summer. Presumably, from examination of the pressure logs, peaking temperatures, such as 309°F in TMP-8, presumably led MDNR to finally raise a cautionary flag about the value of the interceptor strategy as raising undue risks, especially in light of their consultants' view that it also would not work.

By using peak values, the various wells can better be compared to each other, and wide sources of individual variability can be removed, because they include the times when the well's maximum negative pressures were employed.

FIGURE 14 on the following page shows the location of the TMP and GEW wells in the critical neck area overlaid with their recent peak temperatures.[46] As discussed on page 15, the threshold of concern is better considered to be 150°F rather than 175°F. Eight of the 13 gas wells north of the neck in the North Quarry report temperatures in excess of that threshold.

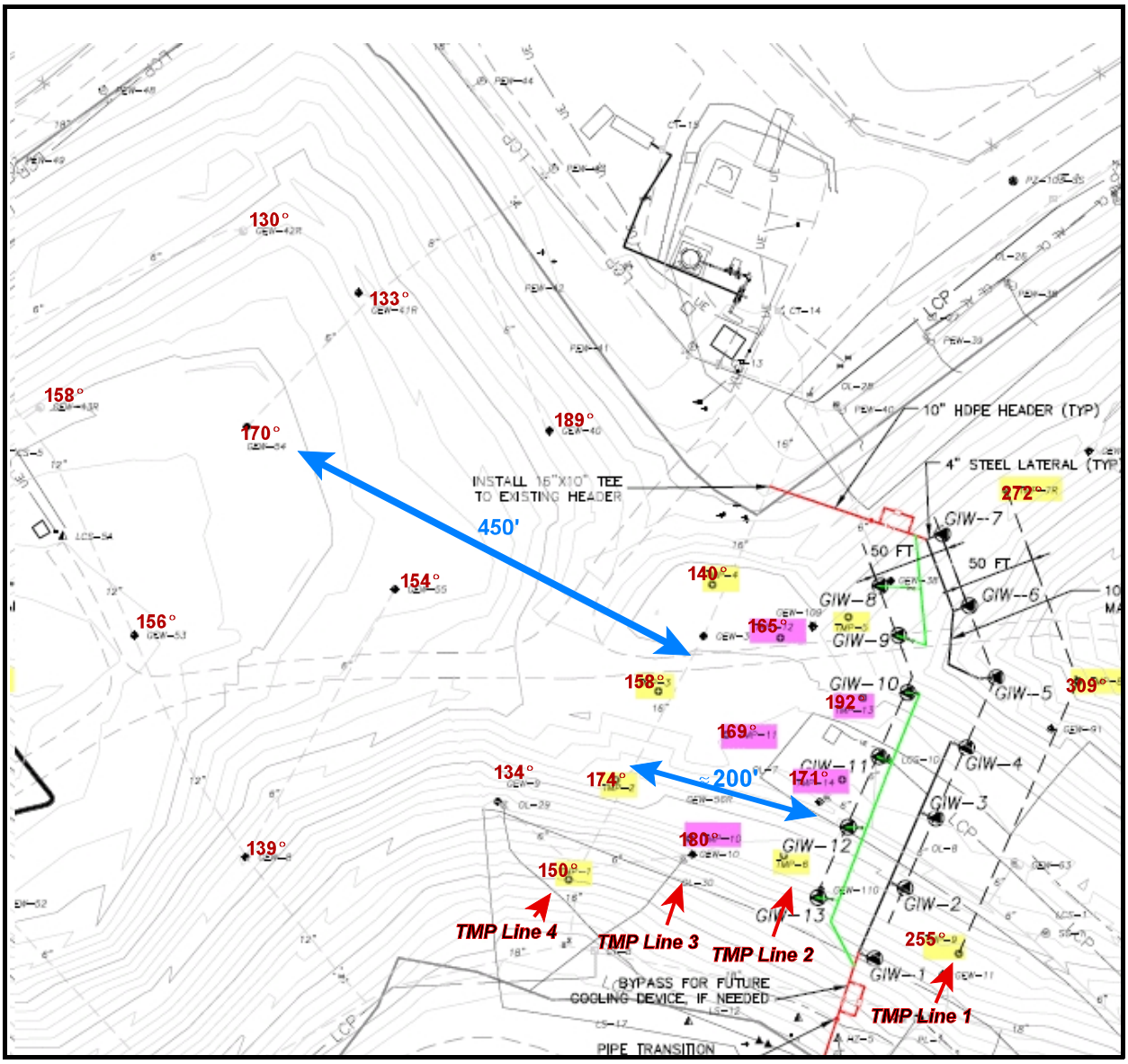


FIGURE 14–Map of location of wells in the neck and North Quarry and their peak temperatures [note North is to the left]

Note that there are four lines of TMP wells, one (TMPs 7R, 8 and 9) behind the two lines of GIWs across the neck. Next, there is a second line (TMPs 13 and 14) amidst the GIW wells; and a third line of TMP wells (TMPs 10, 11 and 12) about 100 feet ahead of the GIW array. Finally, there is the fourth line of TMP wells (1, 2, 3 and 4) about 200 feet ahead of the GIWs and at the northernmost end of the neck. The fourth line of wells, which is the northern most line just beyond the GIWs and the narrow neck, also exhibits elevated temperatures, strongly suggesting that the northernmost edge of the fire has advanced into the southern most edge of the North Quarry, and that the GIW effort has failed.

■ ***The GIW strategy failed.*** Key for assessing the value of Republic's GIW attempt to prevent the fire from continuing through the neck is TMP-2, which is about 200 feet north of the last line of GIW wells. See FIGURE 14. Apart from transient effects due to changes in the vacuum forces applied, the reported temperatures have not significantly declined since the onset of the project last Spring. See FIGURE 15.

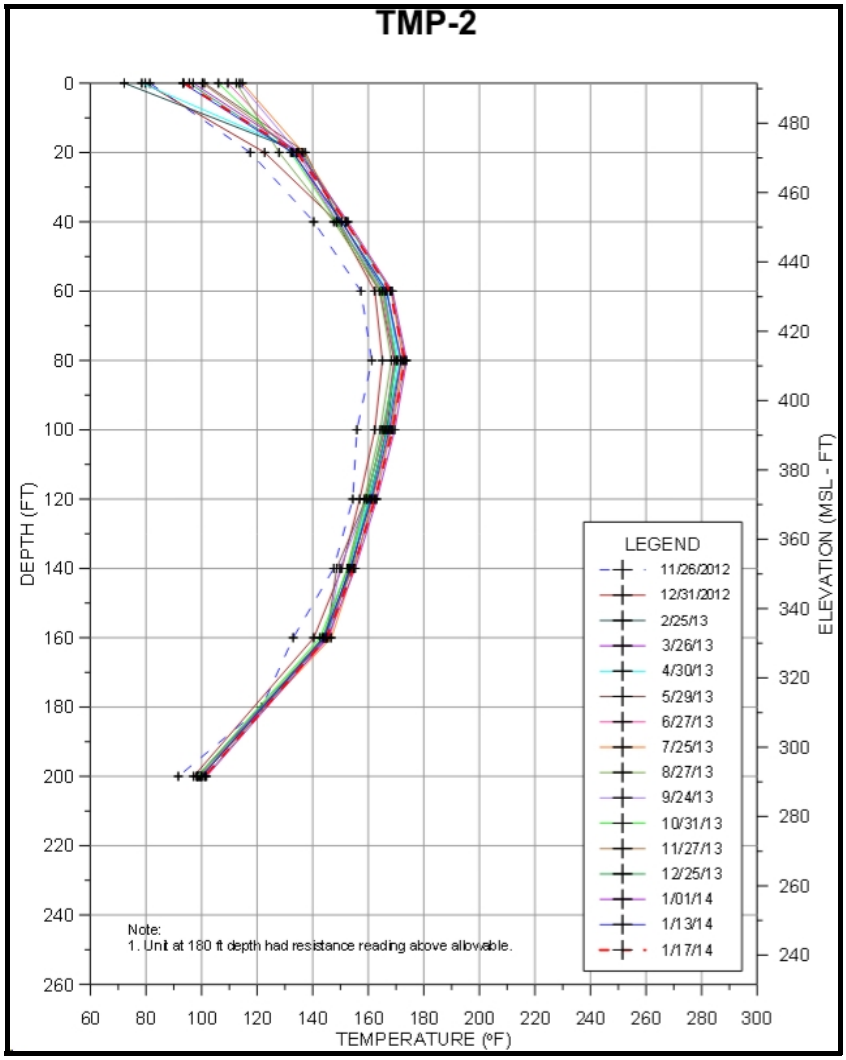


FIGURE 15–Changes in temperature profile in TMP-2 over time

Indeed, instead of decreasing, the graph shows temperatures fairly steadily increasing over the past year from 153°F to 174°F at a depth of 80 feet in that well about 200 feet forward of the purported vacuum wall.

Clearly, Republic's interceptors, which it pursued over the objections of MDNR's consultants, has failed. The fact that it has now been directed to dig an isolation barrier around the RIM section shows that it is all but certain that Republic no longer disagrees. For that effort is only impelled if the fire is advancing.

Not only did the interceptor strategy fail to stop the fire's advance, not only did the time consumed in pursuing GIWs preclude serious efforts to block the fire at the neck, but also, the attempt made the situation for the landfill's neighbors substantially worse.

■ ***The subsurface fire has likely spread past the neck into the southmost edge of the North Quarry.*** The best way to directly track the extent that the fire has advanced past the neck into the North Quarry would have been to install additional temperature wells at intervals north of TMPs 1-4. For all the problems of maintaining functioning instrumentation inside a landfill on fire, these TMP wells are the best that we presently have.

Unfortunately, this simple step was not done, and the last proposal for three new TMP wells are all arrayed at the northern edge of the North Quarry, across Area 1's southern perimeter.[47] None are proposed to lie between the neck and that line to provide key indicators about the fire's advance. However, inferences from the data that do exist indicate that it is likely, but not certain that the fire has not only crossed the neck, but as it moves into the North Quarry, could join with a legacy fire that has persisted for an extended time, with uncertain but worrisome consequences when they do meet.

For one thing, peak temperatures reported in the four lines of TMP wells show gradually decreasing levels from south, where the fire originated, to the North, as would be expected in an advancing fire. The line furthest south and behind the GIWs (TMP Line 1) reports temperatures of 255°F-309°F; the one amidst the GIWs (TMP Line 2), from 171°F-192°F; the one 100 feet ahead of the GIWs (TMP Line 3), 165°F-180°F; and the last one 200 feet ahead (TMP-Line 3), 140°F-174°F. See **FIGURE 14.**

■ ***The elevated temperatures inside the North Quarry appear to have a different source.*** On the other hand, the high temperatures shown far inside the North Quarry appear to stem from a different origin than the fire advancing from the South into the North Quarry for three reasons: (1) the North Quarry fire and the South's appear to be widely separated; (2) there was an earlier fire in the same general vicinity in the North Quarry in the early 1990s; (3) the carbon monoxide finger prints of the two are different; and (4) the extended duration of the North Quarry fire.

■ **Distance from the neck.** As was shown in **FIGURE 14**, the elevated temperatures inside the North Quarry center on GEW-54, which had a peak adjusted temperature of 170°F last year and GEW-40, at 189°F. That peak North Quarry reading is separated from the advancing leading edge of the South Quarry fire at the northern most edge of the neck at TMP Line 4, by about 450 feet. Between the peak North well and the neck, the intervening wells GEW-55 and GEW-9 suggest declining temperatures from GEW-54's adjusted 170°F to 154°F to 134°F. Thus, the declining temperature isobars around the peak temperatures in the North and in the South Quarry suggest two distinct underground fires.

■ **Legacy fire in the North Quarry from the early 1990s.** Prior to the 2010 fire in the South Quarry, in 1992, and possibly again in 1994, there apparently were earlier underground fires in the North Quarry in the same vicinity as today's GEWs 40, 43R, 53, 54 and 55, where elevated temperatures are now being observed. The right hand yellow band of the 1992 fire overlaps where GEW-40 now shows the highest elevated (adjusted) temperature of 189°F in the North Quarry. See FIGURE 16.[48] The close proximity of the two fires could speak to a common source.

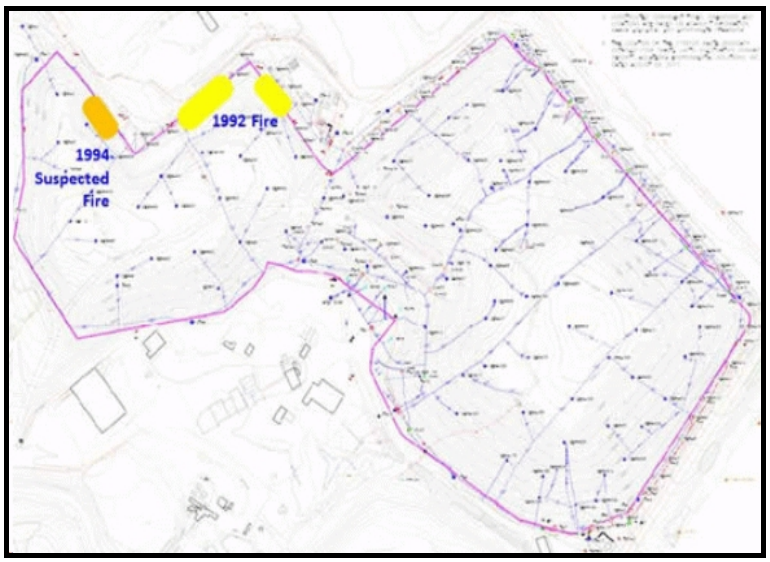


FIGURE 16 –1990s subsurface fires in North Quarry [North to left]

■ **The North Quarry fire is probably due to metal-water reactions unlike in the South.** The mere fact of elevated temperatures underground in different parts of a landfill does not necessarily mean that they both are due to the same phenomenon. Combustion of hydrocarbons in the presence of oxygen and a source of ignition, such as occurs in a fireplace, is the typical fire, and it releases very high levels of carbon monoxide (CO) above 500-1000 ppm.[49] But combustion is not the only source of elevated temperatures, and those who are attempting to dismiss the fact of another underground fire in the North because of the absence of CO misunderstand the multifaceted nature of landfill fires, or perhaps intend to mislead. For, another not uncommon source is of heat sufficient to mobilize radiotoxins are reactive metal-water interactions[50] such as the aluminum dross fire ignited by imprudent leachate recirculation at Republic's Countywide Landfill in Ohio, which has been burning unabated so far for 10 years.[51] The fact that an unknown admixture of industrial detritus was buried in the North Quarry between 1974 and 1985[52] makes this site a prime candidate to see these kinds of chemical reactions that produce excess heat as a byproduct.[53] Unfortunately, because there was no systematic reporting of the types of wastes received in the effectively unregulated site in the pre-Subtitle D era, it will be extremely difficult to deduce what particular reaction is ongoing in the North Quarry until Republic analyzes samples from the bottom of the wells in the North Quarry with elevated temperatures. In any event, the fact that the gas wells in the North with elevated temperatures exhibit very little CO, while those in the South show extremely high CO levels, is consistent with the South's being due to combustion, and the North's to metal-water reactions, which produce no CO. See TABLE 3.[54]

Temperatures and Carbon Monoxide Levels in Selected North and South Quarry Gas Wells on February 20, 2014			
	GEW	Adj. Temperature (degrees Fahrenheit)	Carbon Monoxide (parts per million)
North Quarry	53	151	120
	54	156	24
	55	140	32
South Quarry	38	181	2400
	58R	142	2900
	91	200	4500

TABLE 3

■ **The duration of the North Quarry fire possibly points to its reactive metal origins.** Although the ontological origins of the North Quarry fire are unclear, the fact that it potentially could have begun in 1992 and continued for the 22 years to the present is consistent with a reactive metal process, as evidenced by the Countywide aluminum dross fire.

However, the key point to takeaway from this analysis is that, as discussed on page 25, anything that elevates temperatures above about 200°F for extended periods in the Bridgeton Landfill will mobilize radiotoxins into the atmosphere, regardless of the type of reaction. The fact that little carbon monoxide is released in the process does not, as Republic appears to suggest, somehow convert the reality of the elevated temperatures into something harmless.

■ **It is impossible to predict how fast the fire will advance from the neck through the North Quarry other than to note that it quite possibly could leap forward**

Critical to any analysis of what should or can be done next to reduce the probabilities of even worse untoward consequences is the question of how fast the South Quarry fire will advance through the North Quarry to Area 1, where a significant fraction of the radioactive wastes still remain.

In mid-2013, from what was known then, MDNR's consultants concluded that, after a short pause in the narrow neck between the two quarries, the South Quarry fire would resume advancing at 2 feet per day through the North Quarry. Two feet per day is the rate that the fire had been advancing before it reached the neck, where it slowed down temporarily due to the constriction that had been partially filled with inert rubble.[55]

That rate would suggest the fire could reach Area 1 within 1 to 1½ years after it resumes its movement, which leaves a very short time to complete the isolation barrier now being investigated for the southern perimeter of Area 1.

Unfortunately, a careful examination of the data that has emerged since then casts doubt on whether there is even that year and a half left to act. For one thing, as noted above, the best current interpretation of the North Quarry fire is that its source lies in metal-water reactions.

At present, fortunately no movement has been detected around the North Quarry fire centered around GEWs-40 and 54 has been detected, which is very good thing in view of the 700 feet separating it from Area 1. But, if there is a metal-water reaction in the North Quarry that is generating the elevated temperatures, that could create extremely serious complications when the South Quarry fire reaches the south edge of the North Quarry fire only about 400 feet distant.

Too little is presently known about the causes of the North Quarry fire to make a prediction. But, the very fact of that unknown means the very real possibility cannot be excluded that the combination of the different fires and temperatures could cause the fire to leap forward toward Area 1 at a much faster rate than 2 feet per day.

Another factor that complicates the task of predicting the fire's advance toward Area 1 is the isolation barrier itself. Digging a trench creates an entry point for oxygen to enter the heterogeneous waste mass, with its many passages for ingress, which could cause an underground fire to leap forward several hundred feet essentially overnight. While the underground fire seems to be concentrated 80 feet below grade, while the shelf is only about 50 feet deep at the lip of the shelf, the oxygen can easily be driven 50 feet or more deep into the wastes on days with high barometric pressures.

Essentially, with all of these new imponderables, there is no longer any way to make a reliable projection of the rate of the fire's advance from the South towards Area 1.

THE RADIOACTIVE WASTES ARE NOW VOLATIZING AND BEING RELEASED FROM THE BRIDGETON LANDFILL

Before the fire reaches the remaining radioactive wastes in Area 1, right now the fire in the South Quarry is interacting with the dispersed radiotoxins, especially alpha emitting particles, released from the West Lake/Bridgeton Landfill into the air or ground or surface waters. The vector that poses the greatest immediate threat to the public is from the radioactivity escaping into the atmosphere because the impacts there are immediate while groundwater flows are usually delayed and diluted .

For the radioactivity to escape into the air and disperse widely, several factors must align–

- The radionuclides must volatizate in the conditions of the underground fire
- Those isotopes must lie in proximity to the fire.
- Gas pressure must be sufficient to force the gaseous radionuclides out of the landfill
- The release velocity must first be sufficient to widely disperse the gaseous radionuclides
- The gaseous radionuclides must be lighter than air in order to not precipitate out and fall back to earth
- Over time, people must be susceptible to injury from the radionuclides

■Radium and thorium isotopes can volatize at high temperatures or at lower temperatures that persist for extended periods

Volatization occurs when heat transitions a solid to its gaseous state, which mobilizes it to be released into the environment. Whether that transition occurs is a function of, among others, the form and surface chemistry of the radioisotope, the intensity and duration of the fire, and the vapor pressure.[56]

A study by Puad and Noor was done on the conditions necessary to volatize in an incinerator thorium and radium isotopes,[57] which the *Alverez Report* establishes are the predominant part of the radionuclides of concerns buried in Area 1, not barium sulfates. See FIGURE 17.[58]

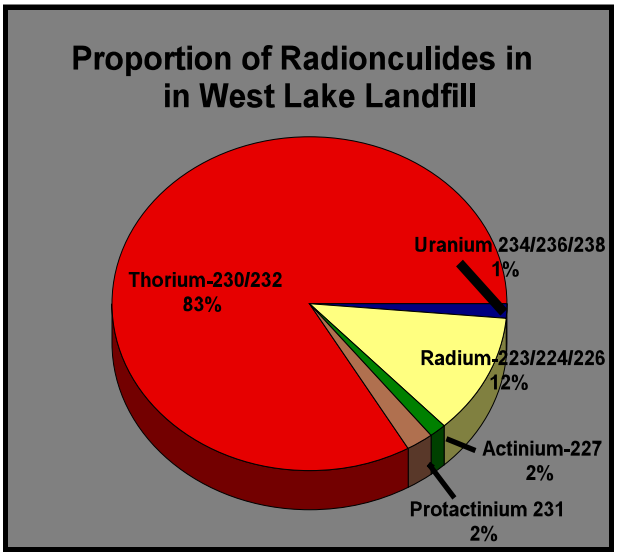


FIGURE 17

While an incinerator chamber does not exhibit identical conditions to a landfill fire, the findings are sufficiently similar to be instructive.

Key here is the researchers' findings that, even though the radionuclides melting points are in excess of 1200°F,[59] first, vaporization begins at the temperature that water boils. Second, with prolonged exposure over time, radioisotopes can be completely volatized at those low temperatures, as can be seen in FIGURE 18, which reproduces TABLE 4 from the Puad analysis.

Table 4
Average percentage of volatilization of ^{238}U, ^{232}Th, ^{226}Ra and ^{228}Ra in crude oil terminal sludge after combusted (experiment)

Nuclide	Combustion temperature (°C)	Percentage of vloatilization				
		Combustion period (min)				
		30	60	90	120	150
^{238}U	100	0	2	3	4	5
	300	8	14	20	23	27
	500	7	14	19	25	31
	700	20	33	50	61	66
	800	22	39	54	64	69
^{226}Ra	100	0	0	0	1	1
	300	1	4	6	9	10
	500	4	9	12	15	18
	700	7	13	16	21	24
	800	7	14	20	24	26
^{232}Th	100	1	1	3	4	5
	300	3	6	8	8	10
	500	5	7	12	13	15
	700	7	9	14	17	20
	800	7	11	16	21	22
^{228}Ra	100	0	0	1	2	4
	300	2	3	6	9	12
	500	3	8	11	15	19
	700	7	12	16	20	24
	800	7	13	18	24	26

FIGURE 18 – Copy of table from Puad study showing relationship of volatization to temperature vs exposure

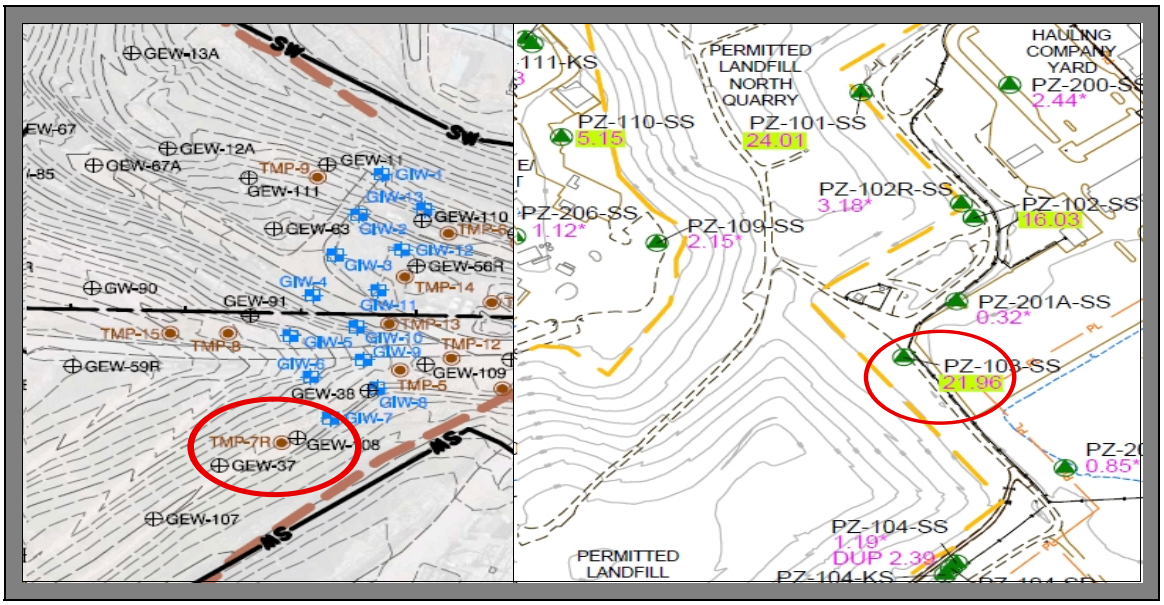
As an example of how lower temperatures can volatize radioisotopes with longer exposure, 5% of Th-230 will volatize at 500° C for 30 minutes, but the same fraction will also volatize at just 100° C if kept in contact with that heat for 150 minutes. At Bridgeton, with an underground fire, the exposure of dispersed radioactivity to elevated temperatures can persist for 20 years

As either temperatures or durations double, the percent volatized increases by factors more, and, over longer time frames measured in months, significant fractions volatize.[60] Once volatized, the pressure wave from the advancing heat front would liberate the radioactivity through cracks and fissures exacerbated by the fire itself.

The fire at Republic's Countywide landfill in Ohio, which was first observed in 2003, continues unabated in 2014, 11 years later.[61] Because major subsurface landfill fires can persist for decades, radium will volatize in Bridgeton even at the low end of elevated temperatures at around 200°F.

■The fire and radioactivity are in contact

The next question that follows is whether there are known points of contact between the intense heat and high levels of radioactivity in the Bridgeton Landfill where the radioisotopes could volatize. FIGURE 19 illustrates the process used in this section to locate areas from where radiotoxins are likely being mobilized into the atmosphere.



Location of Intense Heat from Fire *Location of Proximate Radioactivity*

FIGURE 19–Example of one point of contact between heat and radioactivity [NOTE: North is to the right in the map on the left hand side, and to the top on the map to the right]

The two maps show the point about 200 feet to the south of the narrow constriction on the east side of the neck between the two quarries. The left-hand map in FIGURE 19 is enlarged from that section of **FIGURE 12**, which shows gas wells that provide temperature data. Groundwater wells that provide data about levels of radioactivity are shown in the right-hand map that is an enlargement from **FIGURE 6**.

Circled in red on the left is gas well, TMP-7R, which, on November 27, 2013, reported a peak temperature of 272°F, and circled on the right is groundwater well PZ-103-SS that in April of 2013 recorded radioactivity at 21.96 pCi/l. Unfortunately for visual clarity, the two maps are on different orientations: the left-hand map shows North to the right, while the right-hand map shows North facing up. Once that adjustment is made, the two points, which are both approximately 200 feet to the south of the point of narrowest constriction on the east side of the neck, can be seen as in almost direct contact with each other.

Next, FIGURE 20 shows the co-located points of contact between wells that reported high temperatures and radioactive exceedances throughout the West Lake/Bridgeton Landfills in 2013.

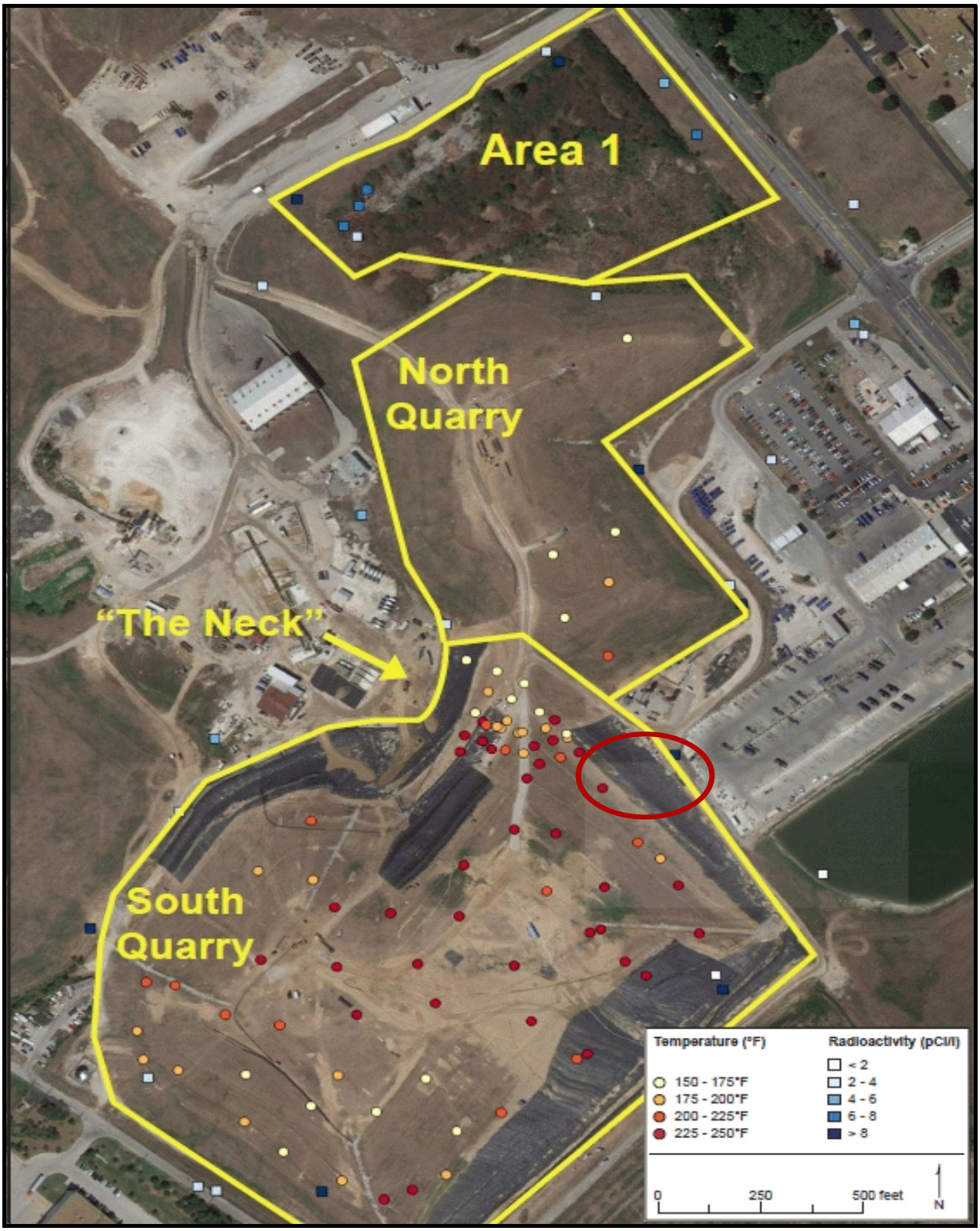


FIGURE 20 – Co-located points of contact between wells reporting high temperature with wells showing radioactivity exceedances above background at West Lake/Bridgeton Landfills

The annotated map provides an preliminary visual means to identify the points in the site where high temperatures are known to be in proximity to high levels of radiation. The paired gas well TMP-7R and groundwater well PZ-103-SS from the prior chart are circled in red here.

However, because of significant measurement limitations, the chart fails to identify much more than it reveals. For one thing, the groundwater wells where radioactivity is measured are only located on the periphery of the landfill. Thus, we presently have no indicators of where levels are similarly high inside the landfill. Nonetheless, as noted on page 4, the sump pumps, which were installed as surrogates for liners, create a cone of depression drawing the radionuclides from the perimeter toward the center of the quarries.

That strongly indicates that radioactivity inside and across the quarries would be even greater than at the perimeter, notwithstanding the absence of instrumentation in the center to establish that fact. For this reason, all of the very hot temperatures in the middle of the South Quarry and in the neck area probably may be presumed to also be in contact with radium and thorium isotopes.

Instead of no radiation in the middle of the South Quarry, more likely the entire span between gas well PZ-107-SS with 11.08 pCi/l on the left and PZ-103-SS with 21.96 pCi/l on the right also exhibits high radioactivity. This indicates the core of the South Quarry subsurface fire, which Republic has identified as being pyrolytic, is quite possibly at temperatures in excess of 1,200°F[70] in proximity to large volumes of Ra-226 and Ra-228, and lesser of Th-230/232.

Even more consequential, worse risks loom in the wings for those near the landfill. Most of the radioactive wastes that have migrated through 2013, as reported, have been Ra-226/228. But, seven times more Th-230/232 than Ra-226/228 was originally dumped in Area 1. See FIGURE 17. Presumably, thorium's relative absence in recent samples is because thorium is significantly less soluble than radium. But, nonetheless, there were five groundwater wells in 2013 where Th-230/232 levels greater than background were found, two of which were in excess of MCLs.[71] This suggests thorium may be a late bloomer, but is not absent, as is shown in the following TABLE of thorium concentrations in samples take in 2012 and 2013 (apparently, none were taken in the prior years' sampling periods).

WEST LAKE/BRIDGETON LANDFILLS
THORIUM EXCEEDANCES IN GROUNDWATER WELLS
(Ordered by Location)

	Well	Location	Th-230 in Groundwater >2pCi/L 2013	2012	2004	1996/1997
RIM	D 85	*ATC*	5.81	7.75	-	-
	D 3	*AMC*	0.17	0.25	-	-
	PZ 115 SS	*AMC*	0.01	0.75	-	-
	S 5	*AML*	0.18	0.45	-	-
AREA 1	S 84	ATC	0.10	1.33	-	-
	PZ 113 SS	ATL	2.37	0.15	-	-
	I 68	ATR	4.14	1.82	-	-
	PZ 112 AS	AML	0.19	0.10	-	-
	PZ 113 AD	AML	0.14	0.11	-	-
	PZ 113 AS	AML	0.23	0.07	-	-
	PZ 208 SS	AMR	0.36	0.47	-	-
	D 14	ABC	1.15	2.19	-	-
NORTH QUARRY	PZ 100 SD	NTR	0.15	1.05	-	-
	PZ 100 SS	NTR	0.10	0.10	-	-
	PZ 101 SS	NMR	0.33	0.13	-	-
	PZ 200 SS	NMR	0.14	0.40	-	-
	PZ 202 SS	NMR	0.39	0.44	-	-
	PZ 110 SS	NBL	0.16	0.29	-	-
	PZ 102 SS	NBR	3.03	0.72	-	-
	PZ 102R SS	NBR	0.27	0.72	-	-
NECK	PZ 109 SS	KML	0.17	0.13	-	-
SOUTH QUARRY	I 73	STL	0.55	0.43	-	-
	PZ 103 SS	STR	6.03	0.88	-	-
	PZ 107 SS	SML	1.01	0.69	-	-
	PZ 205 SS	SML	0.09	2.76	-	-
	PZ 104 SD	SMR	0.17	0.19	-	-
	PZ 104 SS	SMR	0.16	0.30	-	-
	PZ 106 SS	SBL	0.16	0.11	-	-
	PZ 1201 SS	SMR	-	-	-	-
	PZ 204 SS	SBL	0.22	0.11	-	-
	PZ 204A SS	SBL	0.39	0.42	-	-
	MW 1204	SBC	0.12	0.00	-	-
	PZ 106 SS	SBR	0.16	0.11	-	-

TABLE 4

TABLE 4 suffers from a greater lack of time series data for Thorium-230/232 than for Radium-226/228. But, the limited data that we have does show several suggestive changes over a single year.

First, the number of exceedances greater than background rose from 3 to 5; second, the number of exceedances greater than the MCL rose from 0 to 1; and third, the average level of radioactivity rose by 14% from 0.79 pCi/l to 0.90 pCi/l.

This does tend to support the conclusion that, although thorium is relatively insoluble, in the landfill's vertical and horizontal hydrological flows, it is, nonetheless, also dispersing.

Over time, and of great concern, a major wave of increasing concentrations of Th-230/232 can be expected to also migrate out of Area 1. Also, as noted, thorium, like uranium, is pyrophoric, which means that in powdered form it can spontaneously combust, and readily escape, when brought into contact with slightly elevated temperatures at the leading edge of the advancing fire.[72]

■Internal gas pressure provides the motive force to release radiotoxins

The motive force to move the radiotoxins from the landfill to the surface and release it into the atmosphere is normal gas generation, compounded by the fire, and magnified greatly by the possibility of methane and thorium explosions.

■***Normal gas pressure in landfill***. Internal gas pressure building up in the enclosed landfill is the motive force that causes the volatized radionuclides to be released into the atmosphere.

Compliant municipal solid waste landfills produce substantial quantities of carbon dioxide and methane (and trace quantities of hazardous air pollutants) as a byproduct of anaerobic decomposition, primarily of the food scraps and grass clippings in household discards.

Were Bridgeton a conforming landfill, in 2014 it would have generated approximately 160,200 cubic meters of landfill gas in this way. As that gas builds up and expands, pressure inside the waste mass increases.[73] Because of that growing pressure in a confined space, the gas will seek to escape by the path of least resistance through the pore spaces between the wastes in the landfill to the area of less pressure at the surface.[74]

The power that this pressure buildup possesses can be seen by the fact that landfills with a geomembrane cover but without adequate pressure release from an active gas collection system can, almost explosively, blow out the cover, as shown in the photograph along side.[75]

Blown out geomembrane at landfill with inadequate gas collection

■***Ongoing fire conditions amplify gas generation.*** But, of course, Bridgeton is not a compliant landfill, and because of that, for two reasons gas generation is increased significantly over one that is. First are the site's high moisture levels, which increases the rate of decomposition, and with it, more gas generation and greater gas pressure buildup (offset in part by less methanogenesis when temperatures exceed 160°F that kill those microbes).[76]

The second is the underground fire, which, as its heat front advances, also vaporizes the moisture before it in the waste mass, adding further to that internal pressure.[77] Consequently, the already significant forces ejecting the volatized radiotoxins out of this landfill are magnified at Bridgeton beyond what occurs at a normal landfill.

■***Special fire situation creates conditions for a dirty bomb.*** The proximity of the South Quarry, where the underground fire is greatest, to the contiguous North Quarry, where industrial solvents are said to have been buried, and West Lake Landfill, where radioactive wastes were illegally dumped, creates a unique threat. In addition to the risk of explosions from thorium's inherent pyrophoricity, more methane gas pockets may also be explosively ignited by the advancing fire, as happened several times last year.[78]

The violent ejection of radium-226 isotopes from the Bridgeton Landfill, which would spread radioactive debris over a wide area, would resemble a dirty bomb in its impact.[79] To be clear, this would not bear any connection to a nuclear explosion. But, a dirty bomb could release sufficient levels of elevated radioactivity over an extended area that is sufficient, over many years, to cause injury and death. That can create mass panic, not mass destruction, in the surrounding region.

■Gas exit velocity is accelerated

The distance that escaping gases are dispersed from the landfill from their exit point is, along with the type of gas and the wind speed, a function of the gases' exit velocity and the height above the surface that the gases are released.[80] At Bridgeton, the gas's exit velocity is not solely a function of the motive force behind it, but rather is accelerated to a greater velocity at the surface.

Through most of 2013, the surface of the Bridgeton Landfill was covered by just a thin layer of dirt, with no low permeable cover, such as a geomembrane that is needed to prevent gas releases (along with infiltration of precipitation and functionality for gas collection systems). That means that, before the plastic cover was installed, a large fraction of the escaping gas would have not been captured in the gas collection system, because gas collection uses negative pressure to suck out the gas. Without a seal on top, the vacuum forces would also pull oxygen from the surface, which can be explosive when mixed with methane in the landfill gas.[81] At that time before the cover was added, most of the gases escaped as a non-point source, diffused largely across most the site's 52 acre surface (with some through the sidewalls of the quarry where there are lateral paths of lesser resistance).

In an attempt to reduce noxious odors and excess emissions of benzene, an ultra low permeable EVOH/HDPE plastic cover was ordered in 2013 and is almost complete.[82] Due to that effort to lessen the environmental assault on the surrounding community, however, other concerns are worsened due to the law of unintended consequences. Going forward almost all of the gases will now be ejected as point sources, which means at much greater exit velocities. This will occur in two different places.

Part of the landfill gas will be captured in the gas collection system, but that does not mean that the gases disappear. Rather, they will be routed to a flare and burned. The other part will escape mostly through cracks in the cover.

■***Gas through flare.*** Burning the escaping gas through a flue will release pollutants, including radiotoxins, at a greater exit velocity and from a higher elevation above the surface at the top of the stack than previously occurred.

While the non-radioactive hazardous air pollutants should be neutralized in a shrouded flare, the radioactive decay rate of radium and thorium isotopes is unaffected by the incinerator's heat. Critical, as discussed later at page 45, this means the alpha emissions are not neutralized in the flare.

Yet, that greater velocity and the approximate 50 foot height of the flue will significantly broaden the downwind population impacted by the alpha emissions as compared to the conditions prior to installation of the cover when significantly more of the escaping gases were diffused across that highly permeable dirt cover. See FIGURE 21, which shows the location of the two sets of flares at the Bridgeton Landfill closest to residential areas, such as Spanish Village.[83]

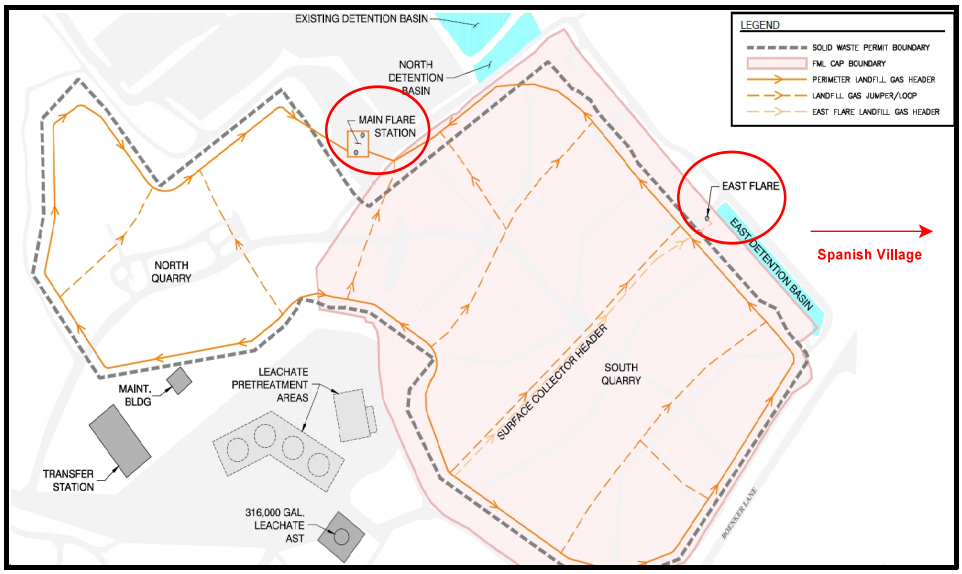


FIGURE 21 - Location of flares (circled in red) at Bridgeton Landfill [NOTE: north is to the left]

The affected area around the Bridgeton Landfill will be expanded even further because of the questionably economical way the company is responding to the mounting fallout from the fire. Republic's action plan states that it will convert from existing shrouded (or closed) flares to less costly candlestick (or open) flares. The intent is to increase the flares' capacity from 9,500 scfm to 11,500 scfm, in order to accommodate increased gas generation anticipated as the fire advances into the North Quarry and a lean burn.[84]

But, this increase in capacity is being achieved inexpensively by effectively removing the shroud from over the top of the flue, whose obstruction acts to increase gases' residence time in the chimney by ¼ to ½ a second. As a result, using the less expensive option to increase the system's capacity will also spread the radiotoxins further, as well as lessen the flare's efficiency in the destruction of the non-radioactive hazardous air pollutants by eliminating that fraction of a second heat buildup. For, the new open flares, which have no shroud, will no longer obstruct and therefore dampen the upward lift and exit velocity of the gases released.[85]

■ ***Gas through the surface.*** Republic has almost completed installation of the ultra low permeable geomembrane over both quarries. As noted, this will dramatically decrease the diffused release of volatized radiotoxins, odors and VOCs from the surface, and funnel more of the gases generated to the gas collection system's flare.

In the last year, and in response to the significant risks created by the underground fire, MDNR ordered installation of that ultra-low permeable geomembrane to impede emissions out, as well as to reduce oxygen infiltration into the landfill. Otherwise, as was explained, gas collection and control over the fire would be seriously complicated by infiltrating air. The cover of the South Quarry was completed in October, 2013, and construction of the North Quarry cover continues at this writing.[86]

Unfortunately, because of the wastes consumed by the underground fire, which has led to voids below, there has been major subsidence of 15 to 20 feet at the surface during the two year

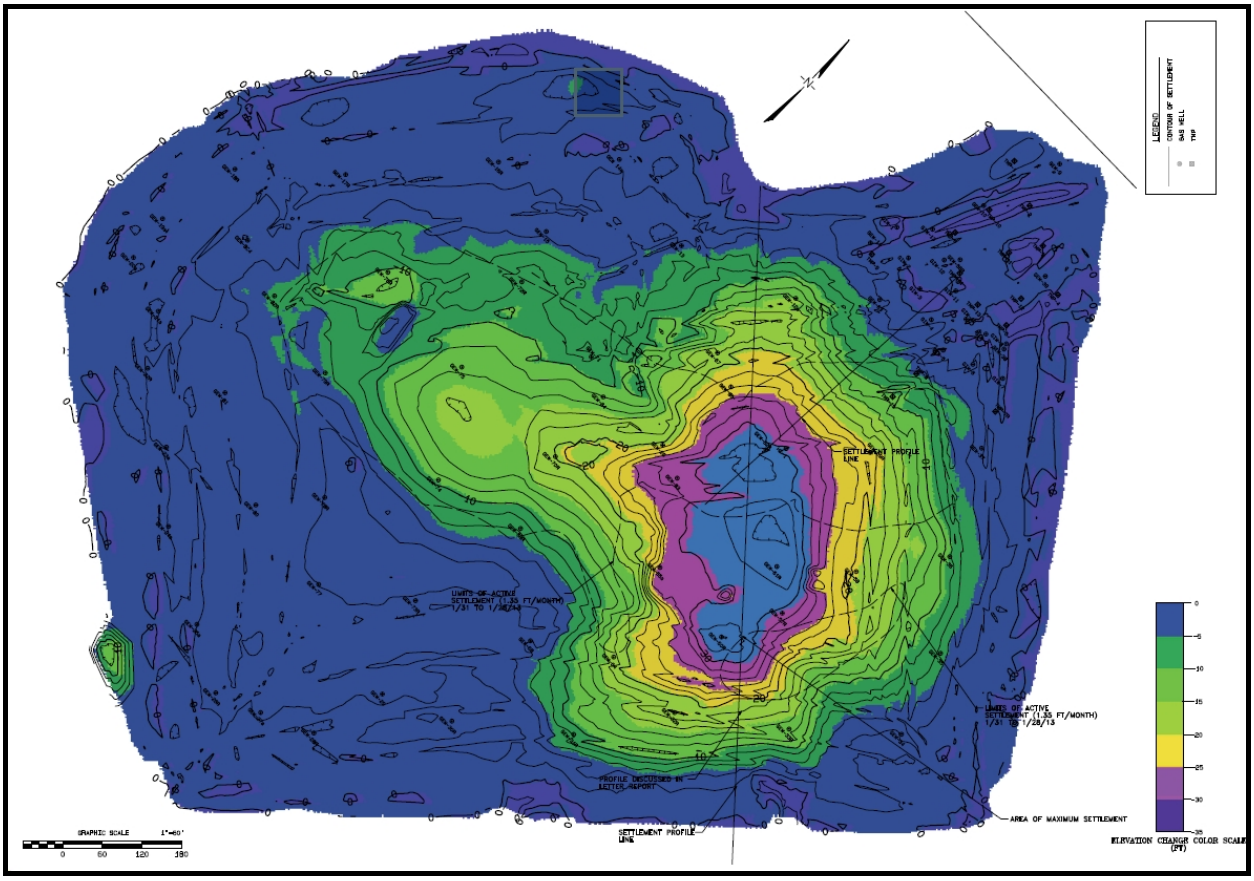


FIGURE 22 – Cover settlement in South Quarry from 3/20/11 to 2/13/13 [north is to the upper right hand corner]

period the underground fire took hold. See the map in FIGURE 22.[87] Republic's most recent monthly report for YE2013 continued to show subsidence of as much as 5 feet in one month.[88]

As the underground fire causes the ground under the cover continues to subside,[89] the new multi-layer cover will tear and degrade to the point it can no longer be patched or perform, but instead will require continued expensive replacement. Until and unless, the leaks are detected, and patching and replacement is done, these nominally strong barriers will soon leak.[90]

Thus, whatever fraction of the landfill gases that are not captured in gas system will now escape through frequent cracks in the new cover. For stresses on the cover will be a chronic problem as the fire continues to cause voids below, and subsidence at the surface, that tears at the polymer or cause the multilayer geomembrane to prematurely delaminate. Also, the heat of the fire will degrade or compromise the performance of the plastic cover.[91]

Gases escaping through small cracks and tears will be ejected in high fluxes[92] rather than the diffused pattern of release prior to the new cover's installation, at significantly higher exit velocities.

■ Alpha particles are lighter than air and travel further

If the gas ejected from the landfills is heavier than air, it may precipitate out before the plume leaves the site boundary. But, volatized alpha emitters are lighter than air,[93] and can be carried by the wind a considerable distance from the landfill.

■ Health effects of radium and thorium can be fatal

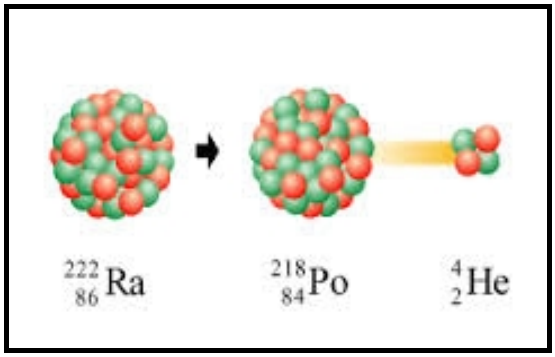
Radioactive isotopes, like those of uranium, plutonium, thorium, polonium and radium, release ionizing radiation that inflict damage on living cells as they pass through or get lodged inside the human body. The toxicity of a radioactive isotope to people is largely a function of the type of radiation it emits, whether the radiation is located and remains in the right place to maximize damage, and how fast (its half-life) it decays.[94]

Because of the uncontrolled fire in at Bridgeton adjoining the illegal radioactive waste dump, the ionizing radiation from the site today turns out to be the worst possible kind that is being released in the worst possible way.

According to the groundwater sampling, radium isotopes 226 and 228 are currently the most prevalent reported radiotoxins migrating out of Area 1 into the north and south quarries where the fire rages, followed by thorium 230 and 232. Thorium is much less a factor now because its relative insolubility has slowed its dispersal, but it will be the dominant isotope emitted in the future.[95]

Both are process residues from work that had been done by the Mallinckrodt chemical factory between 1942 and 1966, in downtown in St. Louis, to refine uranium, originally out of rich Belgium Congo pitchblend. Most of the uranium had been removed, but thorium, radium and uranium residues remained. More radium bearing wastes apparently also came from Lake Ontario, New York, in 1948 and left by the St. Louis Airport.[96]

Both are also alpha emitters. Alpha particles can be the most dangerous form of radiation, but only if they get inside the human body. Though lighter than air, at the subatomic level, alpha particles are large, lumbering positively charged helium nuclei with two protons and two neutrons. Each alpha particle that is emitted cannot, as gamma radiation can, travel far or penetrate a barrier thicker than a sheet of paper or the human skin. However, if they do penetrate the human body, the nuclei will collide with molecules in human tissue and tear that molecule apart through its electric force causing far greater damage. In the process, the alpha nuclei also displace electrons from other atoms that creates two electrically charged particles, and that causes additional damaging changes in other cells.[97]



Radium isotope decaying into daughter product and alpha particle

In addition to the toxicity of alpha radiation is the extent to which it acts on the body. Too short a half-live of a radioisotope and its radioactivity is quickly spent: too long, and the rate of emissions is too slow to inflict much damage. Radium's half-life of 1,620 years is almost ideally pitched to maximize damage to living cells by submitting them to a constant stream of strong ionizing radiation for more than a life time extending for hundreds of years. Its extreme toxicity is widely considered to be 20× more destructive than gamma radiation. Moreover, putting aside plutonium's potential for mass destruction as fissionable fuel in an atomic bomb, radiologists have considered radium's capacity to damage the human body, if it gets inside, to be, gram for gram, 50× greater than plutonium's. For Pu-239 has an attenuated 24,100 half-life, and, thus, that much slower a rate of decay.[98]

Finally, although the radium isotopes that are volatized and ejected can readily be inhaled, many other radionuclides would be soon expelled in the urine. Unfortunately, because, chemically, radium resembles calcium, the body tends to permanently deposit some of the radium inside the bones, where, over a lifetime, its radioactivity continues to degrade marrow and mutate bone cells.[99]

For all of these reasons, the uncontrolled subsurface fire has tragically created the precise set of conditions needed to maximize damaging exposure of the people in the community to the significant ongoing release of the worst radiotoxins from the landfill.

At high exposures, the effects of acute exposure are manifest soon afterwards, including skin burns, followed by death, in a predictable pattern. But, that is not what is to be expected here, where we are seeing long term and chronic exposure to low dosages. These are far more subtle and elusive to pin down with the weak epidemiological tools available to us. They are thought to include lymphoma, bone cancer, and diseases that affect the formation of blood, such as leukemia and aplastic anemia, which take years to develop, and inflict harm probabilistically.[100]

The question faced by those who live near the landfill is whether the low levels to which they are now being exposed exist below some threshold where damage no longer occurs. That sort of concept about a safe dose for low exposures to ionizing radiation may have some abstract logic in its sense of a point above which there appears to be a statistically significant increase in illness or death among a large population exposed to some level of the radiotoxin – or at least it might, were it not for the infirmities of epidemiological analysis when the sample sizes are small and data ambiguous.

A person does not get half a cancer anymore than they (or at least the distaff side) might become half pregnant. Rather, whether one becomes seriously ill or dies from inhaling an alpha particle is a probabilistic (or, technically, "stochastic") matter. Also, the severity of the cancers have not been found to be a direct function of the dosage.

At the individual level, then, as statisticians quibble endlessly about which adjustments are best made to make sense of garbled data, these probabilities are not considered by most people as functions of R-squared values. Rather, they are experienced as whether one wants to play dice with the chance of living to see their daughter grow up and marry, or worse, with whether their children will have their lives aborted before coming of age. Unfortunately, there is no way to objectively reconcile these two fundamentally different ways of looking at the same thing through different lens because messy statistics are no more objective than human feelings.

Presumably, almost everyone living downwind of the landfill is at serious risk and is considering relocating, while those who may be at fault are seeking to evade responsibility. Thus, financial considerations inevitably intrude into this calculus, whether it is the party responsible for the fire, or those innocent people who seeking to be relieved of this risk, who will wind up incurring the attendant costs.

In cases such as these, experts are brought in by the responsible party who will testify that the risks are *diminimus* and/or too uncertain to reach valid decisions, and not sufficient to warrant compensation to the injured party. Neither these experts, nor those who retain them, live in the affected community or personally confront these risks. This raises the pointed question of whether anyone who profits from their opinion, while not placing themselves and their families at risk, is qualified to opine on a matter that is so dependent on personal judgment unrelated to any objective fact that is dispositive of the issue.

■ Republic's claim that the fire would not release radiotoxins is without foundation

The PRPs, led by Republic, claim that, if the underground fire were to reach the radioactive wastes, the radiotoxins would still not be released, and even if they were, they would not leave the site, because:

- Flames are not visible, and therefore radiotoxins would not be released
- The temperature of the fire is too low to release radiotoxins
- Interaction of fire and radiotoxins would be on cooler shallow shelf
- Any radiotoxins released would not be transported past the site perimeter

None of their representations stand up to examination.

■ ***The absence of visible flames has nothing to do with gaseous releases.*** Republic argues that there is no fire, or risk of release of radionuclides, because there are no flames visible at the surface:

> "Flames or smoke do not occur with smoldering events unless the subsurface fire is excavated or otherwise exposed to the atmosphere. Therefore, the release of radionuclides through gaseous emissions by flaming would not occur with a subsurface smoldering event."[101]

Putting aside the fact that Republic's own readings show that the fire has been interacting with the radioisotopes for more than a year (see page 28), this must be one of regulatory history's more audacious instances of an illogical non-sequitur.

Flames are usually not visible because underground landfill fires typically occur out of sight under 100 feet or more of waste overburden and smolder rather than burn in the conventional sense. But, just like in a fireplace, when the hearth has become very hot as the logs smolder in a shimmering pale blue light, that is because there is an efficient fire. It is not an "event", which could just as well be a birthday party as the catastrophic situation that it is threatening the public health and economy of north St. Louis. It is a fire in contact with dangerous radioactivity.

More important, odors and pollutants, such as benzene, liberated by the fire, undisputedly have been documented to escape, transported with the methane and liberated by the pressure wave from the advancing heat front through cracks and fissures exacerbated by the fire itself. Indeed odors complaints have been filed by residents five miles from the landfill.[102]

As explained earlier on page 25, the prolonged elevated temperatures from the fire would also volatize and release the radium isotopes. The pyrophoricity of the impending wave of thorium isotopes creates even greater levels of concern.[103]

■ ***The radiotoxins will be mobilized by the fire.*** Republic also argues that the radiotoxins will not volatize into their mobile gaseous form:

> "The RIM at the site consists of leached barium sulfate residue mixed with soil. The melting point of barite (barium sulfate) is reported to be greater than 1,300 °C / 2,372 °F (Chem Alert 2, 2007) or 1,580 °C / 2,875 °F (Chemnet, 2013, and Chemicalland, 2013). Therefore, the heat that has been observed and/or could be generated within the landfill materials within West Lake Areas 1 and 2 could not approach the amount of heat necessary to melt or otherwise disrupt the stability of the RIM."[104]

This is not correct. The radioactivity of concern is not barium sulfate, anymore than it is radon gas their report dwelled on elsewhere, but thorium and radium. The melt temperature is not the key metric, as is the combination of temperature and duration that volatizes the element. Finally, the temperature of pyrolysis is very hot not relatively low,and thorium is pyrophoric.

First, as has been established through a comparison of the ratio of isotopes and through forensic resesarch in the *Criss* and *Alverez Reports*, the primary elements of concern in the radioactive wastes are not barium sulfate, a residue of the uranium purification process. Rather, they are primarily Th-230/232 and, secondarily, Ra-226/228, products of uranium decay and mixed with process residues from refining uranium.[105] The company's fixation on radon gas, with its 4 day half life and relative low toxicity, is only an attempt at distraction.[106]

Second, the question is not the melt temperature of Th-230/232 and Ra-226/228, as Republic purports, but rather the totality of the heating conditions necessary for them to be volatized. These are entirely distinct phenomenon that act according to completely different factors, as shown in TABLE 5.[107]

Comparison of Radium and Thorium Melting Points to Heat of Vaporization

	Radium	Thorium
Melting Point	1292°F	3182°F
Heat of Vaporization	54 Btu/lb	228 Btu/lb

TABLE 5

Again returning to the discussion on page 25, the Puad and Noor study showed that radium isotopes began to transition to their gaseous state and mobilize beginning at 212°F, given sufficient duration.[108] While their table only showed 1% to 5% volatization in the short few months that they analyzed, at that temperature and after the five months of the study, the proportion of the radiotoxins that volatized *doubled* with each additional month. That is to say, all of the Ra-226/228 could be volatized before the year is out at that relatively low temperature. All of that pertains to the edges of the fire. At its core where pyrolytic conditions exist, the migrating radionuclides would experience temperatures likely to exceed 1200°F.[109]

Third, all parties and textbooks concur the temperatures in the core of the fire reflect pyrolytic conditions. Yet, Republic contends, mis-citing Foss-Smith, that with pyrolysis, "the thermal reaction takes place in an oxygen starved environment and the combusting material is consumed very slowly and at *relatively low temperatures.*"[110]

That is contrary to pyrolytic principles that reflect hotter, not lower, temperatures. What Foss-Smith actually stated about the temperatures of pyrolytic landfill fires is "[t]he temperature at the centre of the pyrolysis mass is difficult to measure but, during a controlled experiment in Finland, a temperature of 700°C [1292°F] was measured."[111]

Fifth, another cause of hyper-elevated temperatures arises from the location of subsurface landfill fires. Because they occur in a confined space deep underground with approximately 100 feet of overburden, runaway conditions have been observed to occur when the heat from the initial fire at 175°F to 250°F reaches and then exceeds the rate at which the system can dissipate the heat, resulting in a further escalation in temperatures.[112]

Sixth, as explained on page 32, thorium isotopes, and in their powdered form can ignite when heated in the presence of air.

Clearly, the overwhelming facts show that the fire is releasing radiotoxins into the atmosphere surrounding the Bridgeton Landfill.

■ ***The fire has reached the radioisotopes in the gravel pits not on the shelf.*** Republic claims that, if the fire and radioactive wastes intersect, that will not occur until and unless the fire were to reach the shallow 40 to 50 foot deep shelf at the north most end of the North Quarry where Area 1 is located (see FIGURE 1). Contact would not, Republic contends, happen in the deep quarries where the fire began because it holds the view that the radioactive wastes have not migrated. The shallow depth on the shelf, it is argued, will both dissipate the heat from the fire and also provide less loading pressure from above that otherwise builds up the excess heat from the fire down below.[113]

As explained on page 4, the radioactivity has widely migrated from Area 1 throughout the deep North and South Quarries over the past year and possibly longer. That is where the isotopes and fire are now interacting, and volatization is presumably greatest in the South Quarry where the heat is most intense.

Later when the fire does reach the remaining fraction of the original radioactive wastes still in Area 1, the other part of Republic's arguments are speculative without substantiation. Also, they are too generally described to be usable. For the possible fact that some heat is dissipated and heat buildup is lessened tells us nothing whether they will reduce the temperature of the fire enough to prevent the radioisotopes from volatizing. As discussed on page 23, the fire was once thought likely to reach Area 1 sometime the next one to two years, but new data suggests earlier.

■ ***The radiotoxins released by the fire will travel downwind from the landfill.*** Republic not only denies the possibility that the radium and thorium isotopes will volatize in proximity to prolonged temperatures as high as 1200°F for several years. It also claims that, even if releases were to occur, they would be localized to the perimeter of the underground fire:

> "While the impacts might increase the rate at which radon is released from the ground, these effects are expected to be localized given that the heat and steam fronts associated with an SSE event would be localized to the perimeter of the SSE and would stop when the SSE reaches the waste mass boundary. These impacts would also be temporary since they would stop when the SSE ends."[114]

No basis for Republic's claim is provided to evaluate. What the foregoing evaluation clearly demonstrated at page 25 is that the radium and thorium isotopes will be volatized, released and transported to the surrounding neighborhoods downwind of the landfill. Republic has put forward nothing to suggest otherwise by its unsupportable attempt to divert attention to the minor issue of radon gas away from the major issue, the volatization and release of Ra-226/228 and Th-230/232 into the atmosphere.

BRIDGETON'S FATALLY FLAWED SITING AND DESIGN, COMBINED WITH THE FACT THAT A SUBSURFACE FIRE CANNOT BE EXTINGUISHED AND IS INTERACTING NOW WITH RADIOTOXINS, MAKES THE DETERIORATING SITUATION LARGELY UNMANAGABLE

Because of an historic series of major errors by Republic and its predecessors, the threat to the well-being and economy of north St. Louis is so great that regulators need to act to reduce those risks.

The unprecedented challenge to the state officials, in turn, is that the several owners' deplorable siting, design and operating decisions over more than 29 years leave little room to maneuver today. For one thing, attempts to patch leaks and cracks in an unlined landfill perched in the water table of the Missouri River flood plain that is on fire is a prescription for failure, as can be seen in the continuing weekly reports of well and cover failures and odor alerts on MDNR's webpage.[115]

To that must now be added that, in perhaps one of the cruelest ironies, not only are the available tools for regulators and managers only marginally adequate to reduce odors. Most important is the fact that as to radionuclides, which is the most critical risk factor, at best, remedial efforts will fail to confront the release of intractable radioactivity, and, more often, actually make those matters worse.

In consequence, this fatally flawed landfill is inherently a sieve that cannot be managed to prevent the release of radiotoxins into the atmosphere and groundwater from the ongoing interaction of the fire spreading from the south and the radium and thorium isotopes migrating out of the north. As is discussed in the section that follows this, the only constructive option left to reduce the threat of a multiplying the release of alpha emissions is to excavate a fire break around the remaining radioactive wastes that have not yet migrated out of Area 1 – if the task can be completed in time. Unfortunately, there is probably less than a 10% probability that this can be done in time.

But, for the two chief remedies in the North Quarry, regulators are caught between Scylla and Charybdus. They will be blamed for the failure to take action if they do not, and for the unintended negative consequences if they do. These involve installation of a–

- Geomembrane cover and more heat resistant gas collection wells
- Pretreatment facilities for leachate captured by perimeter sump pumps
- Isolation barrier around the southern perimeter of Area 1[116]

■Gas flares do not neutralize radiotoxins

The intent of installing a geomembrane cover and adding more gas collection wells has been to minimize releases of odors, toxic substances and radioactivity into the atmosphere. Things will not, unfortunately, work as planned with regard to the radioactivity.

Ironically, that same gas collection system, meant to work integrally with the geomembrane in order to prevent the release of fugitive landfill gas or the blowout of the cover also does something that was not intended. That is to provide another pathway for the migrating radionuclides to be released into the atmosphere, even if we assume the system were capable of operating as designed. As a result, this is another example where the severity of the Bridgeton's siting and design flaws makes it impossible to safely manage the challenges the fire has created.

Briefly by way of background, in the anaerobic environment of a landfill, decomposition of the discarded food scraps and grass clippings yields gas as one of the byproducts, of which about half is methane.[117] Methane, a potent greenhouse gas, also helps strip out the toxics in their vapor state from the wastes, and transports them as a hazardous constituent of the gas.[118] Heat from a subsurface landfill fire further increases the transition of toxins to a gaseous state,[119] and the proportion mobilized, including Ra-226/228 and Th-230/232.[120]

Unfortunately, a geomembrane is not capable of containing the build up of pressure from the expanding space occupied by the wastes in their gaseous state. Unless that pressure can be relieved, the pressure will blow out the cover and, if there is no basal liner below, migrate laterally into adjoining buildings, where it will create explosive conditions (see the photograph of blown out geomembrane, and the surrounding discussion, on page 33).[121]

A flare at the Bridgeton landfill Photo: Missouri DNR

For these reasons, in addition to the composite cover, gas wells, consisting of perforated 7" vertical PVC or HDPE pipes, are drilled through the waste depths about every 300 feet apart. They are maintained under negative pressure in an effort to extract the landfill gases from the field surrounding each well, relieving the pressure and partly controlling for the release of methane and hazardous air pollutants.[122] Equally important, and reciprocally, had there been no plastic cover on top, gas collection could not have worked, because the vacuum forces it uses to pull gas would also draw oxygen from the exposed surface, short circuiting the system. For infiltrating oxygen from the surface creates explosive conditions when mixed with methane below.[123]

Radiotoxins are not supposed to be present in the gas extracted by these collection systems at municipal – which are not hazardous – landfills. Bridgeton Landfill, however, adjoins a radioactive waste dump, and groundwater studies show that the radioisotopes have dispersed throughout the landfill where 117 gas extraction wells continue operating amidst the major underground fire that the operator caused. Also, a comparison of elevated temperatures from the fire and the range that the radioactive wastes have migrated shows that the radioisotopes are volatizing. Therefore, the gas captured at Bridgeton Landfill will contain those radionuclides, and, this is the irony, will actually wind up defeating the protective intent of the composite cover and gas collection system.

Put aside the fact that, even when operated at a conforming site, gas collection systems perform poorly.[124] Put aside, as well, that at Bridgeton, with its myriad non-conforming siting and design conditions, gas collection will be even more significantly degraded to a sub-marginal state.[125]

In addition to all that, and most fundamental to understanding the magnitude of the problem here, the radiotoxins at Bridgeton that are mobilized and captured in the gas system do not somehow disappear.[126] Rather, the collected gas is routed through header lines to a flare,[127] which combusts the landfill gases at between 1,000°F to 2,000°F,[128] which is intended to achieve a 98% destruction rate.[129] See FIGURE 23.

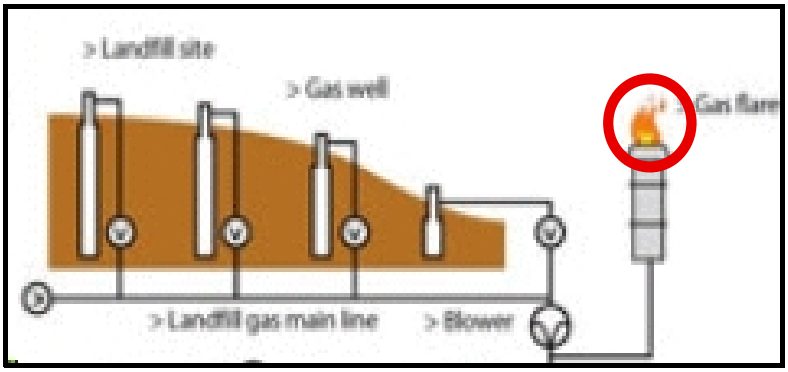


FIGURE 23– Diagram of gas wells routed to flare

That is sufficiently hot to neutralize the mercaptans, which cause the distinctive odor from rotting garbage; hazardous volatile organic compounds (VOC), such as benzene; and halogenated compounds, such as chlorine.[130]

There are concerns about dioxin and furan formation from chlorine as the gases cool down in the stack.[131] But, put those aside, too, to address even more critical matters. For the overarching concern at Bridgeton is the fact that radioactive isotopes are not neutralized in the flare.

The fact is that radioisotopes cannot be destroyed by incineration. Those radium and thorium atoms that were illegally dumped at West Lake emit ionizing radiation from nuclear decay at a constant unvarying rate. Most of those other non-radioactive hazardous substances may be converted into more benign forms in the elevated temperatures of the flare. The radiotoxins, on the other hand, will continue releasing alpha particles at the same constant decay rate, with the same half-life, independent of whatever oxidized form they may take in the stack.[132]

Furthermore, once the radioisotopes are combusted in the flare, they are ejected with greater exhaust gas velocity from a taller height out the flue stack, and distributed over a wider distance than the trajectory they otherwise would have followed.[133]

Therefore, instead of preventing the release of alpha particles, the gas collection system itself is providing its own distinct pathway to release radioactivity into the atmosphere. Worse, these system disperse the radioisotopes even more widely into the atmosphere than would uncontrolled release diffused through a dirt cover. This remains the case even for as long as the ultra-low permeable cover is able to retain its structural integrity from the stresses of the underground fire.

The reason why this escape route for radioactivity has remained out of sight is because it is invisible and odorless, and the gas flows through the extraction system have, disturbingly, not been publicly analyzed for alpha, beta and gamma radiation. Instead of critical information, much of the voluminous gas data reported to MDNR is of comparatively marginal interest (methane, carbon dioxide, oxygen, nitrogen, hydrogen).

Indeed, Republic's recalcitrance has deviated so far from acceptable norms that the Attorney General was compelled to seek a court order to access something as basic and with the right of the State to seek as the company's carbon monoxide data.[134]

■ **The leachate pretreatment system will not treat radiotoxins**

The original irresponsible siting and design decision decisions at Bridgeton Landfill massively increased the volume of leachate generated. To that, the underground fire compounded the problem by elevating BOD and benzene levels in the leachate to the point that the region's sewage plants were no longer allowed to accept those contaminated volumes for treatment.

Republic has had to install pretreatment facilities to re-qualify its leachate for sewage treatment to avoid the site becoming constipated. But that will not prevent the high levels of radioactivity, which also contaminates the leachate, from escaping the site.

■ ***History of Bridgeton's leachate sump pumps.*** At the outset of the 1990s, there were, reportedly, 10,000 or more unlined open dumps in the U.S., many of them contaminating drinking water supplies. In 1994, EPA's Subtitle D rules required all those existing garbage dumps that did not comply with the new liner-based code, of which the West Lake/Bridgeton Landfill numbered, to shut down.[135] Included in the rules were, among other things, the limitation on sites in flood plains, the requirement for 5 feet of separation with the high seasonal water table, liners and composite covers,[136] all of which Bridgeton Landfill violated.

In order to avoid being shuttered, Laidlaw, the predecessor company that owned the Bridgeton Landfill, apparently claimed that the use of large sump pumps to pull leachate from the quarries, in the middle of an alluvial flood plain with a high water table, would create a cone of depression that would be a functional equivalent of liners.[137]

Republic removes central leachate sump pumps

The question lingers how this wholly implausible scheme could have been permitted. The answer appears to be that, notwithstanding the noble intentions of environmental statutes,[138] which have largely remained on the books, in practice enforcement has been crippled. The combination of hostility by elected officials in a climate where discourse is overwhelmed by campaign contributions, the de-funding of agency staff positions necessary to perform the assigned tasks, the derogation of public service and regulatory capture, has been corrosive. By design, in most cases, regulation only resides on the margins or, on a precious few occasions, and for a brief time, in response to a major public tragedy.[139] Thus, Dean Buntrock, the founder of modern vertically integrated waste firms, and his chief aid, Philip Rooney, told *Forbes*, "Regulation has been very, very good for the business."

Presumably, too, little forethought was given to the challenging inevitable consequence, which we are seeing today, of managing an unconfined, perpetually saturated waste mass, half of which is organic matter. The task resembles using straws to empty a bathtub in which the faucet is has been left wide open. Initially, 6 large sump pumps towards the center of the two quarries were used.[140] Later, after the fire disabled those sump pumps and they had to be excavated, Republic, the current owner, began to transition to perimeter sump pumps.[141]

■ ***Enormous volumes of leachate generated.*** When rainfall or snow melt above an open landfill infiltrates the site, water percolates through the wastes and, in the process, forms leachate. Most lined landfills in operation with a functioning leachate collection system only experience significant levels of leachate formation during the occasional period of prolonged heavy rain. After the typical site fills up and is closed with a low permeable composite cover, only minor volumes of precipitation continues to infiltrate the landfill, even during storms.[142]

Not so at the Bridgeton Landfill, which is unlined and hydrologically connected in the Missouri River flood plain in a high water table. Consequently, normal background conditions at Bridgeton are exceedingly high leachate volumes, which, at times of major precipitation, are even more pronounced. Every day, Republic is receiving up to 240,000 gallons of leachate, including condensate from the gas wells (about half of the volume of landfill gas is water vapor).[143]

Of note, if this 52 acre landfill had been developed in accordance with the applicable regulations, we estimate that less than 44,000 gallons/day of leachate would be generated.[144]

However, until the underground fire that was first observed in 2010, the operator could discharge directly to the nearly sewage plants and manage the high volumes by distributing the effluent among several different nearby sewage plants.[145]

■ ***Fire intensifies contamination of the leachate.*** The enormous volume of leachate at Bridgeton is a function of the original irresponsible siting and design decisions. The undisputed high benzene levels, on the other hand, are presumably a result of the fire that followed later,[146] which was caused by design and operational errors.[147] The same might be said of high levels of radioactivity, even though they have been dismissed by the company.[148]

■ **Benzene.** Prior to the fire, benzene levels in Bridgeton's landfill had occasionally shown modestly high readings.[149] Only after the fire has persistent benzene exceedances been observed greater than 1,000 parts per billion (ppb). That is a magnitude greater than the acceptable levels of 130 to 300 ppb for nearby sewage treatment plants.[150] This benzene breakout is not unexpected. Historically, toxic readings spike after a major subsurface fire.[151]

With high levels of benzene and BOD, since the fire Bridgeton's leachate can not longer be directly discharged through the force main via nearby tie-ins to the Metropolitan Sewage District. Instead, the contaminated leachate first has to be pre-treated.

■ **Radium**. Ignored in the plans to pre-treat leachate is the fact that elevated levels of radioactivity has also been found in the leachate, which saw a pronounced uptick in levels from <11 pCi/l to >20 pCi/l around April of 2013, reaching an apex of >200 pCi/l by the end of that month. That was coincident in time with a rapid elevation in subsurface temperatures beginning in late March of that year,[152] which can be expected to significantly increase volatization and mobilization of the radionuclides, as was explained on page 25. See FIGURE 24.[153]

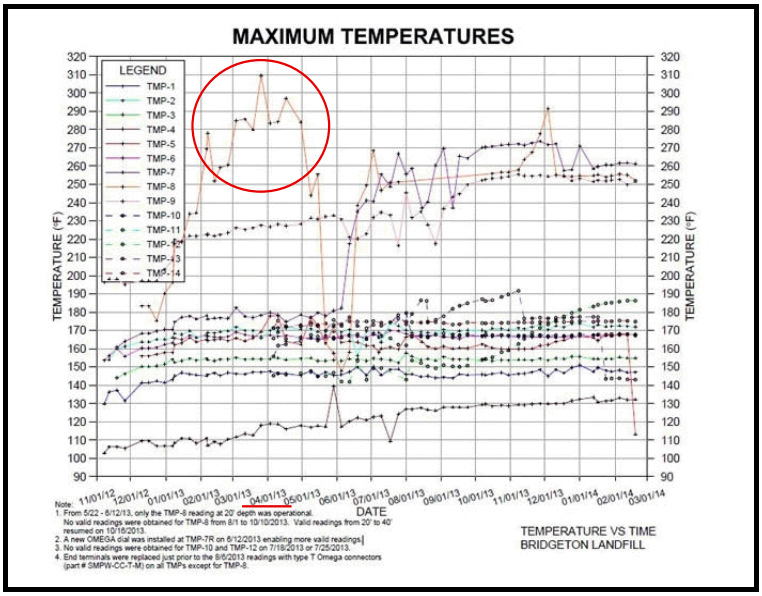


FIGURE 24– Maximum temperatures of TMP wells

If, as the data provided in response to our open records request shows,[154] the leachate is contaminated with elevated radioactivity, that can be expected to similarly hamper the company's ability to find a willing treatment plant operator.

Republic discounts these high readings because its consultant dismissed the extremely high alpha readings that reached 216 ±106 pCi/l as "background" radiation related to natural potassium isotope deposits.[155]

However, putting aside the incredulous attempt to characterize persistent elevated readings greater than 200 pCi/l, as background, this claim is also as counter-intuitive as it is conflicted and incoherent. Counter-intuitive because, as discussed on page 7, the groundwater wells on the perimeter of the North and South Quarries are also showing elevated levels of radioactivity more than ten times background.

It is exceedingly difficult to form a theory how it would be possible to have the high readings found on those groundwater wells at the perimeter of the landfill without elevated readings from the leachate that had been pulled into the cone of influence around the former center sump pumps. Now that the center oriented sump pumps are being replaced by ones on the periphery of the gravel pit where the groundwater wells are also located, there does not appear to be any credible hypothesis for a significant difference between radioactivity in the groundwater and in the leachate.[156]

Conflicted because measurements of the discharged leachate, including alpha, beta and gamma readings, are taken and evaluated by consultants retained by Republic. There is a serious problem with this process in that it is not likely that the particular consultants selected by companies, which naturally seek to avoid uncovering problems managing their discharges, will be ones that will carefully and correctly develop and evaluate all of the necessary tests to fully assess the circumstances.

Incoherent because the record in this case reinforces the concern over how far those conflicts can distort professional conduct. The sample of greatest concern was taken on September 13, 2013, and reported extremely high readings compared to MCLs of 5 pCi/l. That sample showed 589 pCi/l gamma, 216 pCi/l alpha, and 819 pCi/l beta.[157] Republic's consultant dismissed these and other high readings as attributable to "naturally occurring" potassium-40 (K-40).[158]

Dr. Criss examined the data and concluded that Republic's conclusions directly contradicted the laws of physics. While the level of radioactivity will vary with the quantity and age of the radioisotope, the ratio of alpha to beta to gamma emissions from a radioisotope remains constant. The results reported, he observed, are completely at variance with the ratios that would occur were all the radiation from K-40. Therefore, either major measurement errors were made, there are other radiotoxins beside potassium involved, or Republic's consultant has an attenuated grasp of the subject matter–

"The first problem with the conclusions of Republic's consultant is that potassium will emit 8 picocuries of beta radiation for every single picocurie of gamma rays. Therefore, given that the measured total beta emissions were 819 pCi/l for this sample, no more than 102 of the 589 pCi of measured gamma radioactivity can be attributed to K-40, so the remaining ~490 pCi of gamma rays clearly originated from other radionuclides. The presence of these additional radionuclides is underscored by the fact that 216 pCi/l of alpha radiation was measured in this sample. Because 40-K is NOT an alpha emitter, it is clear that significant, unnatural levels of these other radionuclides are both present and being discharged into the surface environment.

"I do not know the specifics of how the radiological data were measured and interpreted, but these glaring inconsistencies render it obvious that the public cannot rely on the data and interpretations offered by the Potentially Responsible Parties (PRP), the PRP consultants, or the EPA. No progress can be made until relevant data including proper assessment of background levels are secured by unbiased entities that have no financial or administrative incentives in particular West Lake outcomes. Public safety requires nothing less."[159]

Leachate storage tanks being constructed at Bridgeton Landfill

Data collection and interpretation has been so deficient it is difficult to know with any precision exactly how contaminated the leachate is with radioactivity. However, inferentially, it is exceedingly difficult to form a hypothesis how it would be possible to have the high readings found on the groundwater wells at the perimeter of the landfill without elevated readings from the leachate that had been pulled into the cone of influence around the former center sump pumps.

Now that the center oriented sump pumps have been replaced by ones on the periphery of the gravel pit where the groundwater wells are also located,[160] there is no longer any basis to argue that there is a significant difference between the groundwater and leachate readings.

■ ***Pretreatment of leachate will not treat radioactivity.*** With up to 240,000 gallons each day of benzene contaminated leachate, Republic has had to prioritize installation of systems to pre-treat the leachate in order to be accepted at nearby sewage plants.[161]

This entails four 1-million gallon storage tanks, a 316,000 gallon tank with blowers to agitate and aerate the leachate in order to volatize the benzene, and a thermal oxidizer to combust and neutralize the benzene that off-gases into the head space of the agitation tank.[162]

But, Republic's new leachate pretreatment system is not designed to prevent or even constrain the release of radioactivity in the treated leachate from sewage plants into the Missouri River. Also, unlike in the flare of the gas collection system, in the aeration tank, the radium isotopes will not be volatized into their gaeous form. Therefore, radium will not be routed to the thermal oxidizer, which, even if it did, would not neutralize the radiotoxins. Rather aeration is only indirectly a component of radium removal by helping manganese filtration with ion formation to precipitate the radium to fall out in the sludge, were these additional systems included in Republic's *Leachate Plan,*[163] which they are not.

At least, in this particular instance, the science and technology exists to remove the radium from the leachate if it were added to Bridgeton's leachate pretreatment system, which must also include provision to insure that the contaminated sludge is properly disposed of separate from West Lake.

This should be done. For the tragic decision dating back at least to 1974 that, just because there was a convenient hole in the ground, sited this landfill in an alluvial flood plain, amidst a high and fluctuating water table, and without a basal liner or (until now) a composite cover, that has created a Frankenstein monster. In consequence, the State must now insure that, essentially forever, there will be a competent operator with ample funds to run a pretreatment facility capable of processing 240,000 gallons of leachate each day and eliminating radioactive contamination, along with the benzene. Otherwise the sewage treatment plants will be unable to accept those loadings, and Bridgeton will seize up in a massive case of leachate constipation that could lead to a whole other set of catastrophic consequences.

■ **Leachate not captured in the sump pumps is released to groundwater**

As was graphically shown in the groundwater well tests on p. 4, the radioactive wastes have spread across the Bridgeton Landfill and, therefore, will also contaminate the leachate. As noted, the part of the total leachate load that is collected in the leachate sump pumps passes untreated through the sewage plants into the Missouri River. The other part that is not captured escapes into the groundwater. Of note, Republic's treatment plans do nothing to lessen the release of radionuclides into surface or ground waters.

■ ***Conforming leachate collection systems.*** A conforming landfill will have a leachate collection system (LCS) arrayed along the bottom of a lined landfill. The site will be graded for gravity flow to drain all of the leachate into perforated pipes arrayed in parallel lines about 200 feet apart at the bottom of the landfill calculated to be of sufficient size, adequate slope and number to remove the expected volume of leachate at the site.[164] See FIGURE 25. EPA rules do not permit leachate collection to be done with vertical pipes because they are inherently inefficient, other than for vertical relief wells on an emergency basis when a LCS line is damaged.

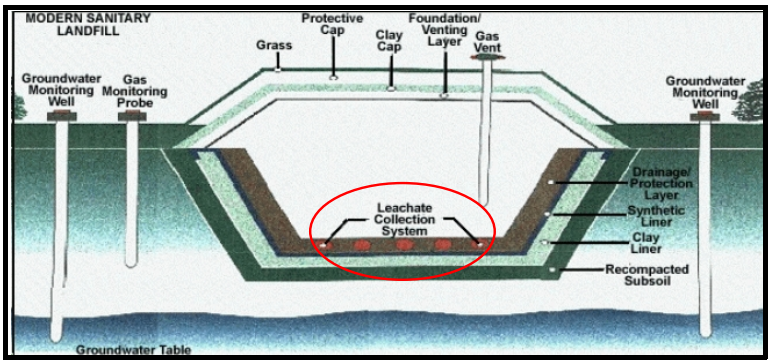


FIGURE 25 – Side profile of lined landfill with leachate collection system

Over time, the leachate pipe, the perforations or the pipe's gravel bed can clog.[165] But, until that happens, conforming sites, unlike Bridgeton, will successfully capture most of the leachate that drains to the bottom of the landfill.

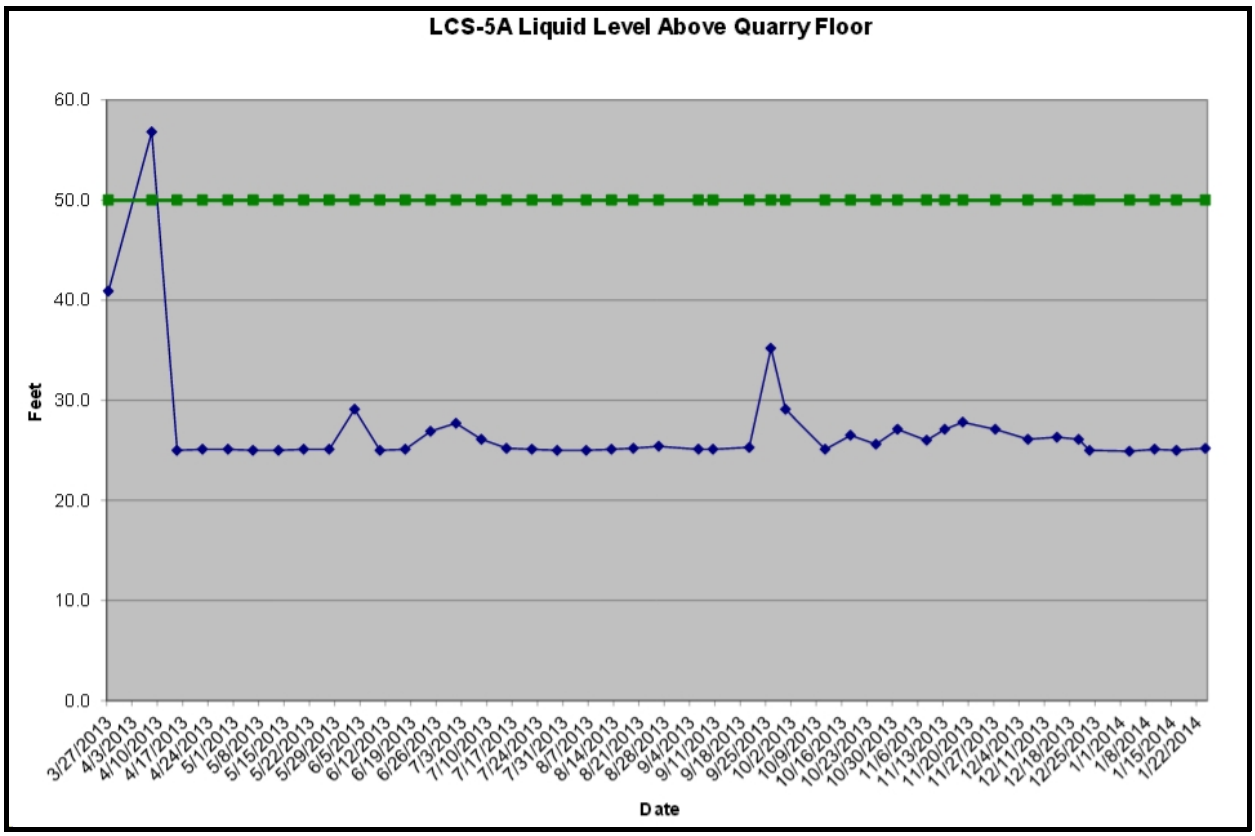


FIGURE 26 – Leachate head above quarry floor around pump LCS-5A

■ ***Leachate that is not captured contaminates groundwater.*** This is not the case at the Bridgeton Landfills. The leachate in Bridgeton does not drain into horizontal pipes. Instead, the site's vertical sump pumps can never approach the systems that are specified in the code to manage leachate because their lateral reach through heavily compacted wastes is necessarily constrained and their vertical reach stops 25 feet or more short of the bottom.[166]

Neither Republic nor its predecessor companies have submitted any data to define how much leachate either the center oriented or periphery sets of pumps are at diverting the leachate away from groundwater, other than measurements of how deep is the leachate head at the bottom of the quarry.[167]

In comparison to compliant LCSs, which restrict the leachate head allowed to accumulate over the bottom of the landfill to a height of 11.8 inches, the Bridgeton permit allows 50 feet and experiences about 25 feet leachate elevations, and those leachate heads are interconnected with the high water table. See FIGURE 26.[168]

Because Bridgeton sits in an alluvial flood plain with a high water table, all of the leachate that is not captured and drains to the bottom of the quarry, which is significant, will eventually be released into the surrounding groundwater. On the one hand, there may be significant dilution, especially as the radioactivity enters the Missouri River. On the other hand, the alpha particles will bioaccumulate.

■ **An isolation barrier will not address most of the present radioactive risks**

The key to Republic's remedial action plan is installation of an isolation barrier between the RIM section (outlined in purple),[169] and the North and South Quarries, where the fire is presently located, as mapped in FIGURE 25 below.[170]

Unfortunately, as regards the radioactive wastes that have already dispersed, the barrier will accomplish nothing, even if it were completed in time. As for the remainder of those wastes that remain in the RIM section or sprawled over the rest of Area 1, there is less than a 10% chance of the barrier's being completed in time, even if there were a commitment to try. More likely than not, the fire will reach the remaining radioactive wastes in Area 1, most of which will be thorium isotopes.

■ ***It is too late for an isolation barrier to resolve the entire crisis.*** Too much has already dispersed for the barrier to achieve all of its intended goal of isolating all of the radioactive wastes originally dumped in Area 1. For much of the rest that remains, including in Area 2, the barrier will not afford protection from other events.

■ **The barrier will not address the dispersed radioactivity.** Most important, the whole predicate for the isolation barrier, shown in green in FIGURE 27, assumes that all of

the radioactive wastes lie behind (and to the right of) the barrier in the purple-shaded RIM section in Area 1, while the fire lies to the south (and to the left) of it.

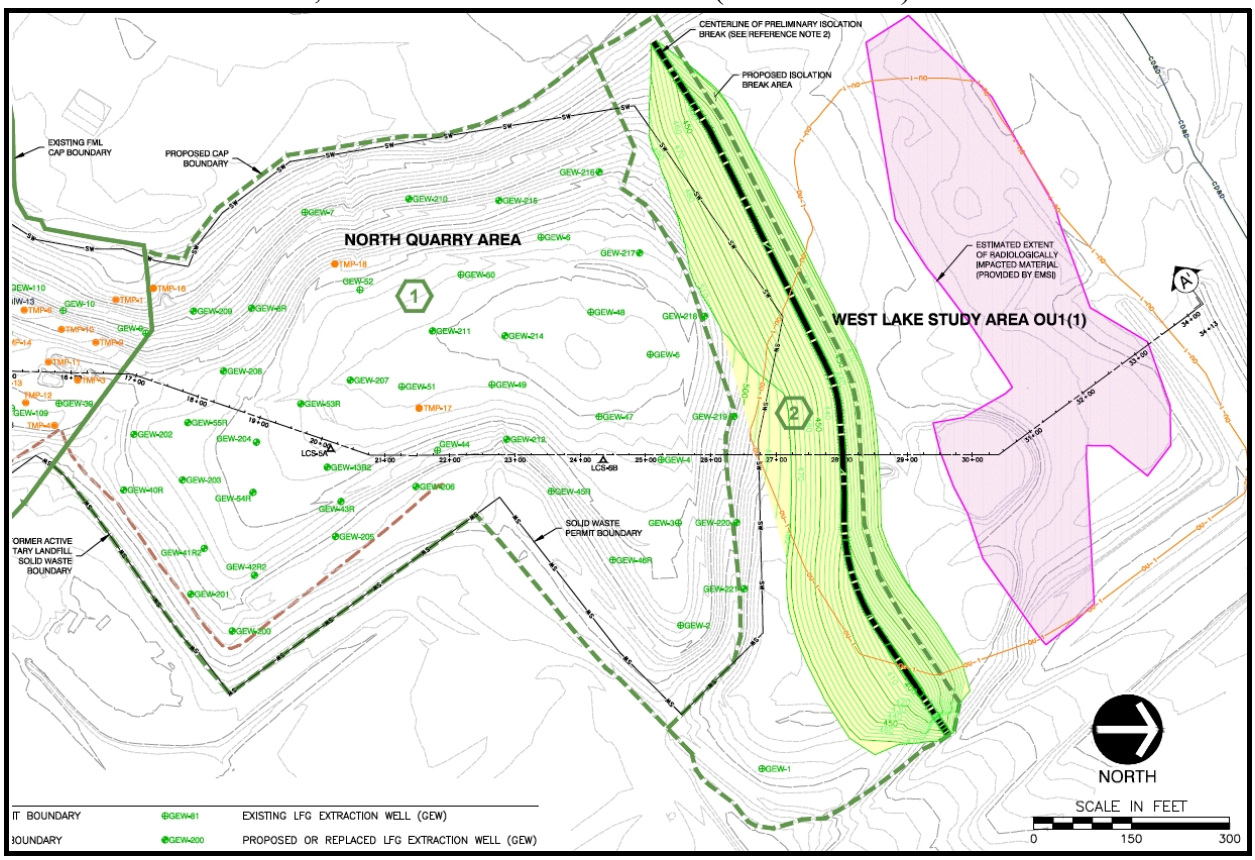


FIGURE 27–Map of Proposed Isolation Break in Area 1 [NOTE: North is to the right]

However, because a substantial fraction of the original radioactive wastes have now migrated outside of that RIM section of Area 1, it is too late to completely, or even largely, isolate the fire from those wastes with a fire break immediately to the south of that section. For a significant, and possibly predominant, proportion of those wastes have already migrated outside Area 1, much of which, as discussed on page 9, has already been in contact with the fire.

That is not to suggest that the isolation barrier should not be constructed – if there is time to do so, it is critical that is done. But, because so much has already dispersed, that needs to be done to prevent a disastrous situation from being compounded further, rather than to resolve the crisis that has already begun. Radiation is invisible and, in low doses, the cancers that alpha emitters inflicts takes decades to be expressed. But, as was documented on page 28, the disaster has been unfolding in slow motion since late 2012.

■ **A barrier would also not protect against flooding.** Also, beyond the concerns about the fire reaching the radioactive wastes that the isolation trench is intended to address, there are other equally serious threats that are not dealt with by Republic's

contingency plan. Flooding from the Missouri River to the west is a significant ever-present risk to the site in the event the Missouri River's flood stage later rises above the 500 year flood level or the Earth City levees fail, as was discussed on page 4.

■**A barrier in Area 1 would not protect Area 2 against flooding.** While the trench would block the advance of the fire to whatever fraction of the original radioactive wastes that remain in Area 1, four times as much radiation was dumped at Area 2. See FIGURE 1. That non-contiguous area about 200 feet to the west of the Bridgeton Landfill is also, and will remain, at risk of flooding. Yet, Area 2 contains 9× greater volume of radiological material than Area 1.[171] See TABLE 6.

West Lake Landfill – OU-1 Radiological Impacted Material (cubic yards)	
Area 1	33,500
Area 2	302,000.

TABLE 6

Area 2 also contains 2× to 6× the gamma concentration levels for different radionuclides compared to Area 1 that was detected in down hole bore testing by the responsible parties in 2000.[172] See TABLE 7.

Maximum Concentration Detected in 2000 pCi/g		
	Area 1	**Area 2**
U-238	147	294
Th-230	9,700	57,300
Ra-226	906	3,060

TABLE 7

■**A barrier would not lessen groundwater contamination.** Contamination of the groundwater at the perimeter of the quarries has already occurred, according to Republic's own groundwater well reports located on the periphery. Therefore, an isolation barrier around the RIM area will not prevent further dispersion of the radioactivity, already migrated outside of Area 1, beyond the landfill site boundary, where groundwater supplies are used for drinking water and agriculture.

Nor will an isolation trench prevent radioactivity that is still inside the RIM from, over time, also migrating to groundwater outside of Area 1. For one thing, there is no barrier slated for north of Area 1. See FIGURE 25 on page 55, in which North is shown to the right, where the proposed trench lies to the south of the RIM section.

For another, the barrier would also not prevent new migration southward, because the trench will not be dug down to bedrock. Rather, the isolation barrier will rest on the shelf at the North end of the North Quarry, underlaid by alluvial deposits, but not extend deeper into those deposits.[173] See FIGURE 28.

Then, 60 to 80 feet of alluvial deposits are below the shelf into which the trench will be excavated, and contaminants can flow out of Area 1 down and through those deposits.[174] See FIGURE 28.[175]

Further, below the alluvial deposits is fractured limestone through which groundwater also can flow.[176]

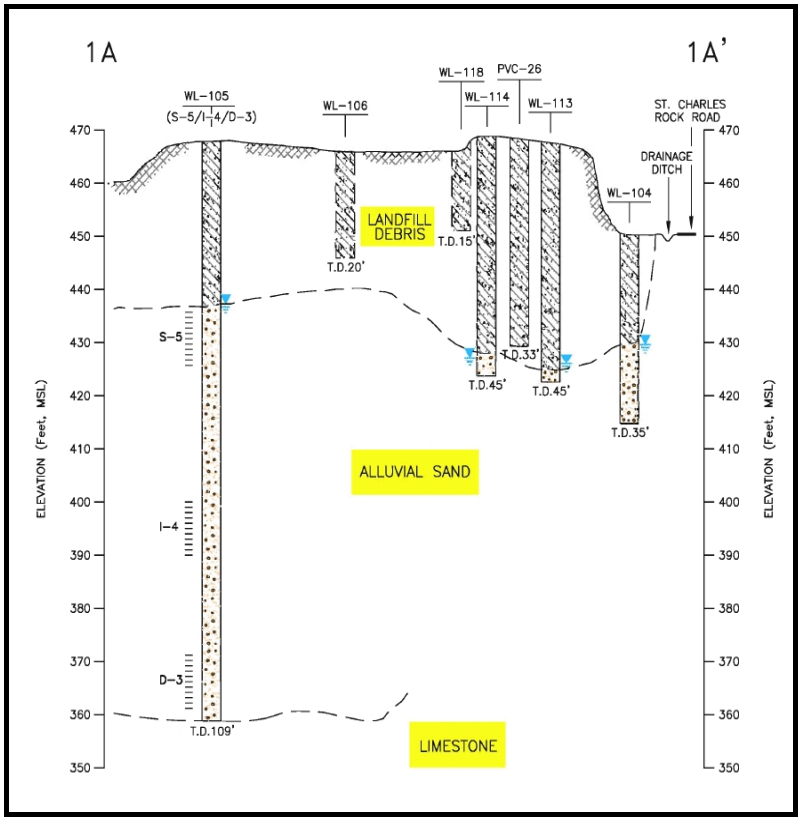


FIGURE 28 – Side profile of subsurface of Area 1

■ ***The chances are dwindling of installing the isolation barrier around Area 1 in time to protect the radioactive wastes that remain there.*** As the several complications become more apparent, the odds of completing the isolation barrier in time dim.

The discussion on page 23 explained that the North Quarry fire now appears to be a byproduct of something like reactive metal and water, instead of a typical hydrocarbon fire. That raises the possibility of compounding effects when the South Quarry fire reaches it, which could be in six months after it breaks through the narrow neck.

Without more information about the specific nature of the apparently independent fire in the North, it is impossible to know how it will react when the fire from the South reaches it. But, in view of the lack of information about what specific hazardous wastes were buried there, conditions that accelerate the underground fire, and speed its advance onto Area 1 are a real possibility.

One example of metal-water accelerators could be as moisture decondenses in front of the advancing heat front when in contact with the cooler wastes ahead of the fire.[177] Another example could be accelerants with ignition points higher than could be created by the North but not the South Quarry fire.

As the risks increase that the confluence of the South and North Quarry fires could accelerate its advance onto Area 1, there is a concomitant risk discussed in that prior section that the act of digging the trench will bring fire-feeding oxygen into the waste mass that could cause the fire to leap forward to the source of oxygen, experts report, literally hundreds of feet overnight.

RECOMMENDATIONS ARE TO IMMEDIATELY EXCAVATE A FIRE BREAK IF THERE IS TIME, EXHUME AREA 1, OFFER RELOCATION ASSISTANCE AND INSURE FUNDS FOR FUTURE REMEDIATION ACTIVITIES

Because of the convergence of dangerous radioactive wastes, a fatally flawed site, appalling design and colossal operating errors that all led to the fire, and to the ongoing release of radioactivity, the situation at Bridgeton constitutes the worst landfill disaster in U.S. history.

In response, unprecedented remedies are urgently required, including –

- Immediate excavation of an isolation barrier along the southern perimeter of Area 1 if it can be done before the fire approaches Area 1.
- Transfer of subject jurisdiction over the site, directly or by contract, to FUSRAP to remove the remaining radioactive wastes at West Lake.
- Offer relocation assistance to those downwind of the landfill.
- Establish financial measures to insure those costs that are assignable to Republic

■ If time, immediately excavate an isolation trench around the southern perimeter of Area 1

The current plan to excavate an isolation barrier along the southern perimeter of Area 1 should proceed, but only if it can be done in time. To do that, work to complete the isolation barrier should be begun in time before the fire may reach Area 1 by FUSRAP if possible and otherwise Republic.

■ ***Work with FUSRAP to complete the isolation barrier if it can be done before the fire approaches Area 1.*** As the Department's consultants and we warned, the remedial gas interceptor wells in the neck not only failed to stop the subsurface fire from advancing out of the South and into the North Quarry. Also, the additional oxygen pulled into the wastes by the wells wound up feeding the fire and elevating temperatures by another hundred degrees or more.[178] That significantly increased volatization and mobilization of the radium and thorium isotopes, as well as of the alpha particles being inhaled by the landfill's neighbors.[179]

The resulting breakout of the subsurface fire into the southern rim of the North Quarry created apprehension among state officials because of the heightened threat to public health and the economy in north St. Louis should the advancing fire reaches the radioactive wastes remaining in Area 1.

Under pressure from the State, last September, 2013, Republic abandoned its attenuated step-wise plan that had postponed critical remedial measures until time consuming testing was first exhausted and trigger criteria were met.[180]

Instead, the company agreed to proceed directly to install an isolation barrier around the RIM in an effort to prevent the fire from reaching the radioactive wastes that still remain there. That is the area where the radioactive wastes are thought to have originally been dumped on the shallow shelf at the northern end of the North Quarry in 1973. Commencement of excavation activity was subject only to the completion of gamma cone testing (which is now done), followed by down hole bore testing, to delineate a corridor along the perimeter where, Republic hoped, no radioactivity above 7 pCi/g would be observed.[181]

The current plan to proceed to directly excavate a fire break was once sound. Unfortunately, these decisions to move forward came late, and implementation by Republic and EPA has slowed to a crawl. Six months have now passed since the original decision to act, without any end to the planning process in sight.

Notwithstanding the site's interconnected hydrology in a flood plain, Republic has seemed genuinely surprised that its gamma cone sampling found extensive radioactive exceedances outside the RIM section. Presumably, that is because the excavation work will now be substantially more expensive than budgeted. Since that time, testing has been revised several different ways, as if EPA and the company believe that some new technique might find a clean corridor through the contaminated wastes, or because of a psychological inability to confront unpleasant facts.[182]

But, these interminable delays need to be seen in relation to several pressing exigencies. Foremost is the rate that the South Quarry fire, which is now at the south-most perimeter of the North Quarry, will advance onto Area 1. The Department's experts projected the fire would move at 2 feet per day, which would leave 1 to 1½ years to the remaining buried radioactive wastes.[183] But, subsequent information suggests that could be much too optimistic.

For, there are other factors that compromise the ability to complete the isolation barrier in time, which were discussed on page 57. They range from the possibility that the fire's movement will accelerate when the South Quarry fire comes in contact with the possible reactive metal at the root of the North Quarry fire, to the risk that the excavation itself will create a path for oxygen to infiltrate the waste mass. That could cause the advancing fire to leap forward if a several hundred feet buffer is not maintained between the two.

If there is to be any realistic chance of installing the isolation barrier in time, then FUSRAP would need to immediately accept responsibility to install the barrier under contract with EPA. That, or EPA should order Republic to proceed with excavation, within the next 60 days, based upon the sampling completed to date.

All this would have to be done recognizing that will involve excavation through wastes contaminated with radioactivity in excess of the MCL plus background radiation levels. Without an uncontaminated corridor, the cost and time to excavate the trench will be complicated significantly. Protective gear, limited exposure times and decontamination protocols could be necessary, not to mention long haul shipping the excavated material to a qualified site. The original $5 million job could easily wind up exceeding $20 to $40 million, as well as consume precious more months to complete. But, that cost premium is just one consequence of the uncertainties that hang over this project. Worse, it is not possible to know how long there is to complete the work.

The best outcome for either party would be if the South Quarry fire, which is now just past the narrow neck, postpones its advance for the next year or longer in order to provide time to complete the barrier. However, because that is not certain, and probably not likely, to happen, the risks are too high to attempt the entire task at once. For, then, a 1200 foot long trench, which would be open for more than year, would permit oxygen into the fill for all that time during which time the approaching fire could take any number of untoward directions that would leave too little time to finish.

To maximize the rate that work on the barrier proceeds, while also minimizing the chance of making a bad situation worse, the 1200 foot barrier should proceed and be completed in segments about 200 feet long so that only that part of that span is open at any time. Each segment should be dug and then filled with inert fill before the next segment of trench is open. That should provide time to continually re-evaluate how much time remains to work on the barrier while there is still time to close up any open trench based upon the latest evidence of the fire's advance.

■ The remaining radioactive wastes in Areas 1 and 2 should be exhumed as soon as possible

The radioactive wastes that remain in Area 1, along with the larger Area 2, should be exhumed to a properly permitted site at the earliest possible time. Jurisdiction over the West Lake Landfill should be transferred from the Environmental Protection Agency to FUSRAP as soon as possible.

■ ***Radioactive wastes remaining in Area 1 and Area 2 should be exhumed.*** For all of the reasons described at length above and in the *Alverez Report*, which are incorporated by reference here, the radioactive wastes that have not yet dispersed beyond where they were originally dumped, and remain in Area 1, along with the larger fraction in Area 2, should be exhumed and moved by FUSRAP to a site permitted for like nuclear wastes.

As discussed on page 56, Area 2 has been found to exhibit 9× the volume and 2× to 6× the gamma concentrations as Area 1 The radiotoxins remaining at the wholly inappropriate West Lake site cannot be left there, and EPA7 has neither the disposition nor the capacity to remove the wastes as circumstances demand.[184]

■ ***Exhumation is essential, but does not address the ongoing disaster.*** A significant fraction of the radioactive wastes originally dumped in the RIM section of Area 1 have already migrated out of Area 1 (see page 4), and is in contact with, and being volatized and released, by the fire (see page 25).

For that reason, exhumation of what remains there, along with Area 2, while essential, will fail to address the ongoing disaster from the ongoing volatization and release of alpha particles from the South, and possibly the North, Quarry into the atmosphere.

■ **The landfills' neighbors who live downwind should be offered relocation assistance**

Relocation assistance should be provided by Republic to those living downwind of the landfill in areas with elevated levels or radioactivity above MCLs

Neither excavation of an isolation barrier between Area 1 and the landfill fire, nor exhumation of the remaining radioactive wastes in Area 1, addresses the ongoing radiation releases from the adjoining Bridgeton Landfill, where those wastes have widely spread and are now being inhaled by those living and working in the vicinity.

■ ***Landfill neighbors face very serious and unacceptable health risks.*** As explained on page 25, dangerous alpha emitting particles are being released through cracks in the landfill cover, or routed through the gas flare, and ejected into the atmosphere. The very serious and sometimes fatal consequence to the health of the landfills' neighbors who inhale the particles are described on page 37. Moreover, in the event time runs out before an isolation barrier can be installed along the south perimeter of Area 1, the radioactivity released will increase by several factors in a very short time.

They are innocent victims, facing very real risks of serious morbidity and mortality to their, and their children's, lives, not because of an act of God. Rather, their predicament is due to the gross negligence of Republic and its predecessors since 1985 –

- The Bridgeton Landfill should never have been sited in an alluvial flood plain, amidst instead of more than 5 feet above the high seasonal mark of the water

- Having been sited where it never should have been, the landfill should have been constructed with liners, a compliant leachate collection system, composite cover and sufficient gas wells

- Sump pumps should not have never been substituted for liners

- A composite low permeable cover should have been installed as soon as the site closed in 2004 and not more than one year later

- The gas collection wells should not have been operated with excess oxygen infiltration

- The narrow neck between the South and North Quarries should have been excavated in early 2012 when there was still time to stop the fire's advance, or, when that was not done, an ice curtain barrier should have been installed across the neck in 2013

Reinforcing the company's negligence here is the further fact that this is not the only landfill where its negligence led to a fire. Republic also caused another major underground landfill fire at its Countywide facility in Ohio by, first, accepting aluminum dross, which EPA had stated should not be accepted in MSW landfills because it was highly reactive with water. Second, Republic recirculated leachate, which dramatically increases moisture to save money, but at the expense of starting the fire that has continued for more than a decade.

Previously when noxious odors problems reached a noxious level during schedule remedial action to remove broken sump pumps, the Attorney sought and received a court order that required to pay to offer temporary relocation assistance to those residing next to the landfill until the problem abated.[185]

Unlike the worst odor problems, which, given sufficient effort, could be managed to reduce their recurrence, the continuing release of dangerous alpha radiation downwind of the landfill is neither temporary nor can it be managed until the fire exhausts all of the combustible fuel and reactive metals in the quarries. Rather, the release of alpha particles will continue for an extended period measured in decades, and that poses the serious threat of irreparable injury and death to downwind neighbors, as was described on page 37.

While it would be a good thing to offer anyone within 5 miles of the landfill relocation assistance to move themselves and their families out of harm's way, the resources are not likely available to do this all at once. A more realistic proposal would be to establish a priority ranking of the adjoining neighborhoods, and offering those worst affected the opportunity to first receive relocation assistance, followed later by lesser affected neighborhoods.

Air dispersion models should be run to draw isopleths around the West Lake/Bridgeton Landfill that show the downwind areas where the highest concentrations of alpha particles are most likely to be found. At those sites most likely to have experienced the highest concentrations, samples should be taken to assess whether the alphas levels exceed the MCLs.

At those downwind areas where radioactivity exceeds the MCL, residents of that area should be informed of those facts and offered relocation assistance for those who chose to move, with those areas with the greatest levels offered assistance first. That assistance would, at a minimum, make the residents whole for their relocation, covering the loss in the value of their home due to the landfill, and the transaction costs of relocating, including appraisals, selling, buying and moving expense.

■ **All measures should be taken to insure that Republic pays for the costs to remediate the costs imposed by the fire it caused**

Financial assurances should be updated on an ongoing basis every six months; the remedial actions negotiated or ordered each year should be staggered so that the costs in any single year do not exceed Republic's free cash flow (≈$500 million); and each requirement should be committed to an order with a pre-established fine for non-compliance that approximates the costs for the State to do the work itself.

Neither Republic nor its predecessor companies had anything to do with the WWII Manhattan Project to develop the atomic bomb. It ought not be held responsible for now exhuming from Areas 1 and 2 the radioactive wastes that were generated in St. Louis to refine uranium, which was illegally dumped at West Lake by a private party with no known relation to Republic.

On the other hand, and as discussed on page 62, Republic's gross negligence directly caused and then worsened the fire, and later it refused to take preventive measures to stop the fire's advance when there was time to do so. Therefore, Republic should bear all of the cost that are incurred to address the specific risks that would not have existed were it not for the fire.

■ ***Future remediation and relocation costs could exceed one billion dollars.*** The present value of the future remedial costs at the Bridgeton Landfill to maintain and operate the specialized leachate pretreatment plant, and to repair and replace the laminated geomembrane cover, just in order to keep the landfill's autonomic systems functioning, could well be more than a hundred million dollars. Then there will be the major efforts required to prevent disastrous events, such as installation of the isolation barrier across the southern perimeter of Area 1 to block the fire's advance that could cost tens of millions of dollars more. Finally, there are the relocation costs that could exceed one billion dollars depending upon the results of the field sampling of the downwind neighborhoods.

■ ***Present law and practice only covers routine maintenance and limited corrective action expenses.*** At present, nothing that is commensurate with the likely costs have been set aside for these costs to insure that the expenses will be paid. Landfill law does provide that the permittee is required to post financial assurances by one of several mechanisms, ranging from bonds to promises, to better insure that there will be funds for the site to be closed and routine maintenance to be continued for 30 years after closure.[186] Basic maintenance primarily includes mowing the grass, maintaining the chain link fence, and periodically taking groundwater and air samples, all as distinguished from "corrective actions." That is the legal term that refers to remedial efforts that have been ordered to address identified problems that had not been anticipated.[187]

According to the company's calculations, the postclosure care expenses only total $8,890,259,[188] and that amount is committed for those routine maintenance costs and are not available for corrective actions needed to address the fire.

■ ***Republic's response to First Agreed Order requirement for updating financial assurances is grossly inadequate.*** The First Agreed Order did require Republic to make a submission to update these amounts to reflect the current situation,[189] which the company nominally did in May, 2013, proposing to increase the expenses for corrective actions from an initial $697,053 to $41,173,890.[190] Incongruously, this was stated at the same time that Republic reported to the Securities and Exchange Commission (SEC) that it expected to spend up to $392 million:

> "In June 2013, we recorded an environmental remediation charge at our closed Bridgeton Landfill in Missouri in the amount of $108.7 million to manage the remediation area and monitor the site. As of June 30, 2013, the remediation liability recorded for this site is $143.4 million, of which $ 64.5 million is expected to be paid during the next twelve months. *We believe the remaining reasonably possible range of loss for remediation costs is $112 million to $392 million*" (emphasis added).[191]

The company may not be giving this issue the seriousness that the Department has requested. In any event, the Department has indicated that action on Republic's proposed update has been placed on hold until events at the landfill resolve themselves more clearly as to what remedial actions will have to be done.

Complicating the question of whether to devote substantial time now to these issues is the following. Financial assurance provisions are best applied before a landfill has opened. At this late date, regulators also need to enforce remedial action through clean up orders as the cost estimates for corrective actions keep evolving. If Republic were to wind up in bankruptcy court, creditors may seek to claim that the financial assurance fund should be used to pay the debts were it not properly segregated.

■ ***Missouri should undertake a comprehensive strategy to prevent Republic from filing for bankruptcy.*** Of great concern, the company has never, nor ever will, receive any revenues from the Bridgeton Landfill. For that reason, its fiduciary responsibility to its stockholders will be to minimize if not avoid any further outlays needed to maintain or fix the closed site. For, of particular note, Republic inherited Bridgeton as an unwelcome piece of a much larger mega-merger with Allied Waste Services in 2008 and has never received, nor has any expectation of ever receiving any revenues in the future from the facility.[192] Moreover, its executives are financially rewarded for meeting earnings growth targets that the costly Bridgeton cleanup erodes.

With the company's reported expenditures for cleanup already exceeding $100 million,[193] the point is rapidly arriving when Republic can be anticipated to conclude the time has arrived to cease cooperating with regulators. Instead, it is presumably already evaluating how to shed itself of any further outlays, such as by declaring bankruptcy under Chapter 11 of the Bankruptcy Act,[194] and reemerging on the other side as a profitable firm shorn of its liabilities, which would be left to the taxpayer.

Thought to be the most egregious example of this strategy is the notorious *Asarco* case. By the 1990s, Asarco's smelting and refining operations had left in their wake 19 Superfund sites around the country, with outstanding environmental liabilities estimated to be $500 million to $1 billion. After being bought out by Grupo Mexico in 1999, Asarco shifted its valuable assets to a subsidiary of Grupo for an artificially low price. With too few assets left to fund the cleanups, the weakened Asarco was headed for bankruptcy. This led the Justice Department to strongly oppose the asset transfers. But, in the end, Justice was forced to settle for a negotiated settlement in which Asarco set up a trust fund of $100 million for cleanup of its contaminated sites that are now estimated to cost $1 billion.[195]

Less well known, but more similar to the landfill circumstances in Bridgeton, is the Pinewood Landfill next to the shore of South Carolina's Lake Marion, which is the state's largest reservoir that lies over two aquifers, and which provides drinking water to the state's coastal plain. The landfill began in 1977 as an old clay pit began a new life as a kitty litter mine, and, a year later was converted into a loosely regulated hazardous waste dump. Thereupon, the landfill went through a succession of different owners. First there was SCA, and then Laidlaw, which later was acquired by Safety-Kleen.

By 1985, regulators had come to realize that the landfill's liners would eventually fail, threatening the water supply for tens of thousands of people. Eventually, they later projected, a major cleanup would be necessary that could cost as much as $1 billion. For that reason, in 1994, the Board of the Department of Health and Environmental Control (DHEC) had required Laidlaw to post a $133 million cash bond before being permitted to expand the capacity of the hazardous waste dump. But only the first $14.5 million installment was ever paid, when the company's decided instead to lobby the legislature to avoid paying the bond.

During the year that followed, Laidlaw spent $250,000 lobbying the Legislature, generating the political pressure to override the Department's technical decision. When the DHEC Board revisited the issue the following year, three new members had been appointed, and they decided to let the operator, itself, determine how to provide financial assurance. Laidlaw offered a corporate IOU, underpinned by its questionable balance sheet.

But, as spring gave way to the summer of 2000, Safety-Kleen, the site's last owner, ominously decamped its offices from Columbus to Delaware, and, thereupon, filed for bankruptcy. Then, in 2004, it offered South Carolina a take-it-or-leave-it $15 million annuity, allegedly worth $49 million, for the long term costs of maintaining the site. In the exceedingly unlikely event anything was left over, that would be no more than a *de minimus* down payment on the possibly billion dollar cost to clean up Pinewood. Even that nominal payment was contingent on their being legally relieved of responsibility for all future liabilities.

"We felt surely they would never go bankrupt" remembered Roger Leaks, who had been one of those new Board members appointed to remove the bonding requirement. "Maybe," he later wondered, "we should have held out for cash." But, by then, it was too late. In the end, South Carolina realized it had little choice but to sign the release in order to get any money.[196]

This is also the path that Dow Corning followed in 1995 when silicon breast implant lawsuits overwhelmed the company following the revelation that its own engineers had warned of the implant's complications 20 years earlier,[197] as did American Airlines in 2011, when it entered bankruptcy, terminated its pension obligations and then returned to the market as a more profitable company.[198]

Prudence dictates that Missouri strategically anticipate the real possibility that Republic will follow in these firms' path when the costs exceed some price point that they have already internally fixed upon. The fact that Republic has resisted the Attorney General's request for something as simple as data about carbon monoxide levels could suggest that that point is approaching.

At the end of this discussion, the key take-away point is that, if at all possible, Republic should not be given the opportunity to petition for a Chapter 11 reorganization. For the essential purpose of the bankruptcy laws is, in general, to prioritize giving the ailing corporation a second lease on life, not to mediate a just resolution of environmental or social controversies that happen to become intertwined. The proceeding has many moving parts, each with its own uncertain outcomes. Case law is still evolving and has not clearly resolved the precise circumstances when the debtor can discharge environmental liabilities. Most of all, with all of the creditors of a $8.4 billion company, litigation can be as protracted as it is contentious, all the while the debtor's assets remain frozen. Indeed, this sort of bankruptcy proceeding can easily consume a decade or longer.

Through the cases, the single legal question of greatest concern to Missouri that resists clarity is the inability of the courts to definitively resolve this seemingly basic issue. Does an enforcement order, which is effectively exempt from the protections that the bankruptcy code accords the debtor, become a monetary claim, which is not exempt, because the order necessarily requires the debtor to spend money in order to comply?

Among the most important specific legal issues that the State will face were Republic to seek Chapter 11 protection are:

- Automatic stays
- Abandonment of contaminated property
- Priority of its claim
- Dischargability of Republic's Bridgeton liabilities

■ **Automatic stay.** The first issue is whether a bankruptcy filing freezes in place all outstanding regulatory orders pending the completion of the reorganization. Upon filing a Chapter 11 petition, the bankruptcy court issues an automatic stay of all pending claims in order to give the debtor breathing room to reorganize.[199] Typically, however, this stay does not extend to enforcement orders issued under the state's police powers. Yet, some courts, which construe orders as claims, have held otherwise. In any event, orders that require cash outlays rather than repairs are treated as money claims that are stayed.[200]

■ **Abandonment.** The second issue is whether the debtor can abandon its assets with large environmental liabilities attached. In bankruptcy court, the debtor is usually allowed to abandon assets that are burdensome or inconsequential, but usually not to avoid compliance with environmental laws.[201] Other courts, however, have carved out exceptions to that general rule, such as when the particular assets do not present the risk of imminent harm,[202] or there are unencumbered assets to maintain the property.[203]

■ **Priority of claim.** The third issue is which of the contending creditors' claims have priority over the others. As discussed, environmental orders are usually not characterized as monetary judgments that are subject to being prioritized for payment by the court according to strict statutory rules. Even if the matter were considered monetary in nature, enforcement orders that arise after the firm has reorganized can be accorded priority treatment as an administrative cost if the cleanup is necessary to bring the debtor's assets into compliance with environmental regulations. That is considered a benefit to the new firm upon emerging from bankruptcy.[204] Unfortunately, the facts here may not be seen by a court as meeting that criteria for that kind of priority treatment because the Bridgeton Landfill is closed and can confer poss no positive value going forward for a reorganized Republic.

■ **Dischargability.** The fourth issue is whether an enforcement order to undertake or continue an environmental cleanup entered before the bankruptcy filing survives the

reorganization. If it does, that requires the reorganized firm to complete the cleanup process.

The first thing to note in regard to this issue is that only those claims that predated the petition can be considered for discharge.[205] In that regard, the courts have expanded the ambit of what is a prior claim that can be discharged to include matters that had not crystalized into an actual order by the petition date, but, at that time, were conceivable (or technically "contingent") based upon the circumstances known at that time.[206]

Also, for those environmental orders that did precede the filing, these enforcement orders had not been treated as monetary claims that could be discharged,[207] until a number of opinions carved out exceptions in cases where the government could have performed the cleanup itself and charge back the costs to the debtor, or where a charge back would legally be considered to be an in lieu of payment. These legal circumstances were treated as having converted the matter into a monetary claim.[208] Enforcement orders under Comprehensive Emergency Response Compensation and Liability Act (CERCLA), which has a specific charge back provision,[209] would be more vulnerable to this *Chateaugay* case counterclaim than would be those under the Resource Conservation and Recovery Act (RCRA), which does not.[210] To date, Missouri has been acting under its state RCRA provisions.[211]

With that background in the bankruptcy laws, there are three types of actions that have been undertaken, or are proposed here, to address the Bridgeton fire that would bear very different prospects of surviving a Chapter 11 proceeding:

- Enforcement orders
- Relocation assistance
- Independent testing

Enforcement orders should hold up best to a Chapter 11 bankruptcy petition, although too little is absolutely certain. Relocation assistance and independent testing by the state (with charge back to the company), on the other hand, may not. They could be construed as monetary claims, which would be treated as unsecured or as dischargable. Thus, if the risks are too significant to those downwind to not offer relocation assistance, the largest cost item in the proposed remedies could be foreclosed by a Republic Chapter 11 petition.

Fortunately, however, petitioners cannot file for Chapter 11 in bad faith. This means that, in the end, in order to have the court confirm a reorganization plan that discharges its environmental liabilities, petitioners must actually need relief in order to preserve the firm as a going concern and to maximize property available to satisfy creditors.[212]

To better prevent a Chapter 11 filing, then, to the extent exigent circumstances permits, the State may want to refrain from front-ending remedial actions, which potentially could make Republic unable to pay its creditors. Instead, regulators could stagger the remedies it orders in any year so the aggregated costs would be less than the amount that could justify bankruptcy. One metric to use as a annual limit would be an amount that reduced revenues to the point that the company could no longer remain a going concern, including paying its creditors. Republic generates substantially more annually than $600 million in free cash flow and slightly less than that in net income, as shown in TABLE 8.[213]

Republic Services Net Income and Free Cash Flow
(in millions)

	2013	2012	2011
Net Income	$588.9	$571.8	$589.2
Free Cash Flow	$691.3	$639.0	$864.8

TABLE 8

Going forward, remedial expenditures could, over several years, total as much as $1.5 billion so long as time permits the isolation barrier across Area 1 to be installed. Against those expenses, these earnings figures suggest it would be financially feasible to impose regulatory clean up and relocation orders that do not cost more than $600 million in any given year, at least for the next two to three years.

That plan would do the cleanup and relocation job while keeping Republic a going concern capable of paying its creditors and meeting its core capital requirements. For sufficient cash flow in that amount is generated internally after paying for the company's cost of operations, including taxes, interest on its debt and replacement of retired property, without having to access outside capital markets, other than for opportunistic refinancings. The losses would fall through to stockholders, either in the form of lower dividends or stockholder's equity.

If Republic did have to raise substantial sums from markets to remain a going concern, this plan, which would lower returns on capital, might meet investor resistance. However, for almost 20 years, the waste industry has been a cash flow story, with so much excess cash flow it has spun off much of that cash for stock repurchases that lifts stock prices. It has not been a growth industry that demands new financings for expansion.[214] There is, after all, little chance of Republic securing antitrust approval to merge with Waste Management in order to tighten the present duopoly into a monopoly.

Dividends may be temporarily reduced if this staging plan were followed by regulators, and stock repurchases would probably be suspended. That could suppress the value of the company's stock for the few years involved. But, the company operations would remain viable, and, in a few years after its Bridgeton liabilities were paid, Republic would be positioned to recover its market valuation, as well.

That is to say, staggered remediation should insure that Republic pays for the costs it incurred, rather than the taxpayer, while only temporarily reducing the return to the firm's stockholders, who, by approving management each year, are ultimately responsible for the fire that the company officials caused.

This plan would fall apart, of course, if there is a rush to the courthouse door by other injured parties, whose total relief requested would bankrupt the company. Possibly, that could be averted if the Attorney General conducted a meeting with the plaintiffs' bar to educate them that, without the discipline to stagger claims over time, everyone will file at once, the company will petition for Chapter 11, all the pending complaints will be discharged, and the attorneys will receive 30% of nothing for their trouble.

On the other hand, if the South Quarry fire does not remain in the neck, time runs out to construct the isolation barrier and the fire reaches Area 1, the relocation costs would be astronomic and all these balancing considerations would be moot.

■ ***Missouri should also revise its statutes and rules in case there is a bankruptcy filing.*** Because it will be so difficult to keep Republic out of bankruptcy in practice, in order to protect the State of Missouri, it should:

- Increase fines for violations in Missouri's solid waste laws
- Enact a super lien statute

■ **Fines.** First, the State should increase fines for violations of Missouri's solid waste statutes and rules,[215] because fines are treated under Chapter 11 as a priority administrative expense. The current $5,000 per day per violation cap[216] is too low relative to the harms created, which fines are properly intended to discourage. But, to avoid discombobulating other industries that have no relationship to the unique situation in Bridgeton, larger fines, of possibly $50,000 per day and per count, should be limited to, and would justified by, only violations of the Missouri Solid Waste Management Act and only at those municipal solid waste landfills adjacent to Superfund sites on the National Priorities List.[217] As violations continue to occur at Bridgeton, the maximum fine should be imposed for each day and violation, but then be temporarily suspended until and unless the deadlines in the applicable enforcement order are not met.

■ **Super lien.** Second, the Legislature should amend its statutes to give the State a super lien on any assets owned by the debtor in, and business revenues derived from, Missouri for remediation costs at MSW landfills adjacent to NPL sites. A super lien confers on the state first priority for CERCLA and RCRA cleanups that is superior to previously perfected mortgages or security creditors in bankruptcy. One survey found seven states with different degrees of super liens: Connecticut, Illinois, Louisiana, Maine, Massachusetts, Michigan and New Hampshire.[218] If Republic's revenues derived from its Missouri operations are proportionate to its population, that would create a priority lien on approximately $159,600,000 in revenues per year for as long as Republic continued operations in Missouri. Also, in the event the company abandoned its Missouri operations to the old Republic in bankruptcy, the new Republic would still own the Backridge, Prairie View and Show Me landfills in Missouri, which could be foreclosed to raise cash for remediation.

Indeed, just enacting these statutory amendments, and thereby drawing a line in the sand, should be salutary. If other plaintiffs' complaints can be managed, passage of these proposals could dissuade Republic from giving further consideration to a bankruptcy petition without these proposals ever having to be implemented. Most certainly, the Attorney General should secure competent bankruptcy counsel to advice in these matters in an ongoing manner.

CONCLUSION

The people who live and work around the West Lake-Bridgeton Landfill have been repeatedly assured by Republic and EPA's regional office that there is no threat of radiotoxins being released into the environment and threatening their lives. For one thing, there was said to be 1,300 feet separating the fire from the radioactive wastes. For another, there is also said to be a fence around the site. Finally, Republic says, even if the fire did interact with the radioactive wastes, none would be released other than harmless short-lived radon gas.

Villa Rosa Lane in Maryland Heights near the landfill

This report examines the data compiled by Republic to test the validity of these assurances and has found them severely unsupported and contrary to the known facts.

In fact, as previous investigations established, the radioactive wastes illegally dumped in Area 1 are not the relatively benign barium sulfates, but mostly radium isotopes. Radium may be relatively harmless if not inhaled or ingested. Tragically, the underground fire that rages uncontrolled across large swathes of the landfill has placed these radiotoxins in direct and extended contact with intense heat. This situation insures that a significant fraction has volatized, and escaped into the atmosphere, where some of the deadly alpha emitting particles are being inhaled by the area's denizens.

Unfortunately, radiation is not something that one can see or smell, and there has been no serious effort to detect these isotopes' alpha emissions, which are dangerous when inhaled, but will not be expressed in cancers until years or decades later. To protect itself, therefore, the community will need to act proactively, and history suggests those urgent actions will not come from Republic, which appears more preoccupied with limiting its financial exposure.

There is only one rational action to take now in order to manage these risks in the best way that can be done under the challenging circumstances. That is, if time permits, to demand the removal as quickly as possible of as much of the radioactive wastes from West Lake that remain in Area 1, where their shallow depth makes it feasible to be exhumed, preceded by the immediate construction of an isolation barrier around Area 1's perimeter. In that way, at least we can minimize the continuing dispersal of more of those dangerous wastes across the landfill.

For the radioactivity that has already migrated out of Area 1 across the quarries, which are too deep to excavate, other measures will be required to protect the area's residents, business and institutions, starting with make-good relocation of those downwind seeking to do so. ❑

ENDNOTES

1 Federal Emergency Management Agency, *Landfill Fires: Their Magnitude, Characteristics and Mitigation* (2002). Ohio Environmental Protection Agency, *Subsurface Heating Events at Solid Waste and Construction and Demolition Debris Landfills: Best Management Practices* (2011); Patrick Foss-Smith, "Investigation Into the Initiation, Detection, Treatment and Prevention of Landfill and Tyre Fires," Dissertation (U. Southhampton, 2010), and "Understanding landfill fires," *Waste Management World* (August 2010); Tony Sperling, "Fighting a Landfill Fire," *Waste Age* (January 2001).

2 MDNR Website Site: Background – Bridgeton Sanitary Landfill, on-line at http://www.dnr.mo.gov/env/swmp/facilities/BridgetonSanitaryLandfill-Background.htm.

3 Google Earth.

4 EPA, *West Lake Landfill Record of Decision* (2008)(ROD), at p. 35.

5 Jeffrey Tomich, "Missouri attorney general sues Bridgeton landfill owner," *St. Louis Post-Dispatch* (March 28, 2013).

6 Letter from Karl Brooks to Sen. Roy Blunt, dated March 21, 2013.

7 Robert Criss, *Risk and Character of Radioactive Waste at the West Lake Landfill, Bridgeton, Missouri* (February 21, 2013).

8 *Id*., at p. 5.

9 40 CFR §§258.11 and 258.40(a)(2).

10 Republic, *Operation, Maintenance, and Monitoring Plan, Volume 2, Gas and Subsurface Control Systems* (September 2013), at FIGURE 1.

11 Republic, Bridgeton Landfill North Quarry Action Plan (November 12, 2013) (Second North Quarry Action Plan), at Sheet 3, at PDF p. 42.

12 EPA Region 7, *Record of Decision on West Lake Landfill OU-1* (2008), at p. 18, and FIGURE 5-6 on p. 67.

13 Engineering Management Support, *Supplemental Feasibility Study Radiological-Impacted Material Excavation Alternatives Analysis - West Lake Landfill Operable Unit-1* (December 28, 2011) (Supplemental Feasibility), at Figure 17.

14 Robert Criss, *Risk and Character of Radioactive Waste at the West Lake Landfill, Bridgeton, Missouri* (February 21, 2013), at p. 6.

15 *ROD*, at p. 1.

16 Robert Alverez, *The West Lake Landfill: A Radioactive Legacy of the Nuclear Arms Race* (November 21, 2013) (Alverez Report), at p. 4. See also *Criss Report* at pp. 1 to 4.

17 *Supplemental Feasibility*, at FIGURE 17; EMSI, *Groundwater Monitoring Report 2012 Additional Groundwater Sampling Event West Lake Landfill Operable Unit-1* (December 24, 2012), at FIGURE 8; EMSI, *Groundwater Monitoring Report April 2013 Additional Groundwater Sampling Event West Lake Landfill Operable Unit-1* (July 8, 2013), at FIGURE 7. The groundwater tests in the 1990s were done in 1995, 1996 and 1997. For readability, the text refers to the three collectively as 1996.

18 EPA Region 7, *Record of Decision on West Lake Landfill OU-1* (2008), at TABLE 5-6 on PDF p. 98.

19 The data was compiled from the reports for Total Radium 226/228 in NOTE 12. To indicate the location of the reported readings for each well with exceedances, the second column in the FIGURE uses an abbreviation system as shown below:

Abbreviations in Location Column

1st Digit	
A	**Area 1 (italicized if in RIM)**
N	**North Quarry**
B	**Bottleneck**
S	**South Quarry**
2nd Digit	
T	**Top**
M	**Middle**
B	**Bottom**
3rd Digit	
L	**Left**
C	**Center**
R	**Right**

A subsequent groundwater study was done in July following the April 2013 sampling. The results of that sample are consistent with the trend of the prior sampling periods. Republic, *Bridgeton Landfill-Groundwater Monitoring Report* (December 1, 2013).

20 EPA Region 7, *Record of Decision on West Lake Landfill OU-1* (2008), at TABLE 5-6 on PDF p. 98.

21 National Primary Drinking Water Regulations: Radionuclides, 65 FED.REG. 76,708 (Dec. 7, 2000).

22 Republic, *Bridgeton Landfill – West Lake Landfill Core Sampling Work Plan Revision 1* (Jan. 8, 2014), at p. 6

23 *Id.*, at FIGURE 2, at PDF p. 46.

24 EPA Region 7, *Record of Decision on West Lake Landfill OU-1* (2008), at p. 21.

25 Ira Levine, *Physical Chemistry* (5th ed.)(McGraw-Hill, 2000), at p. 955.

26 Auxier and Associates, *Baseline Risk Assessment, West Lake Landfill Operable Unit 1* (April 24, 2000).

27 Yug Wae Wang, *Effects of Solution pH and Complexing Reagents on the Desorption of Radionuclides in Soil* (Argonne National Laboratory, 1992).

28 *Id.*, at p. 20.

[29] Washington University, Satellite images of Missouri River (1993).

[30] EPA Region 7 website, Answers to Questions Submitted to EPA Region 7's Online Portal for the West Lake Landfill Site (September 2013), on-line at http://www.epa.gov/region07/cleanup/west_lake_landfill/answers-to-questions.htm. Essentially, EPA Region 7 cautions the need for more study to resolve concerns it now sees in the quality of the data. However, the agency did not express the same reservations when the same consultant, EMSI, previously produced readings that were not so high as to demand action. The question arises why the quality of the data only becomes too uncertain to act when it produces readings that are so high and widely distributed as to demand a major response.

[31] Republic, *Groundwater Monitoring Report* (2012), at pp. 16 to 17. There are four reasons set forth in the report for denying the self-evident meaning of the reported findings, but, essentially, they all assert the claim, namely that the readings above 10 pCi/l are background radiation:

(1) "No contiguous plumes of radiological or conventional groundwater contamination is present underneath the Site or migrating from the Site."

(2) "The levels of radionuclides detected in groundwater beneath and downgradient of the two radiological areas are consistent with the levels of radionuclides detected upgradient of these areas, indicating that the two radiological areas do not contribute radionuclides above background levels."

(3) "[T]he occurrences of radium isotopes in the groundwater are not the result of leaching from the radiologically-impacted materials in OU-1 Areas 1 and 2, but instead reflect naturally occurring (background) levels of the radium isotopes emanating from the bedrock. The consistency of the Site values with regional background levels of Radium-226 and Radium-228, as reported by Szabo (2012) and Lucas (1985), further supports this conclusion."

(4) "The absence of spatial relationship between the RIM occurrences in Areas 1 and 2 and the locations of the highest occurrences of Radium in groundwater indicates that the levels of Radium-226 and Radium-228 found in the area of the Site are of natural origin."

[32] EPA Region 7, *Record of Decision on West Lake Landfill OU-1* (2008), at TABLE 5-6 on PDF p. 98.

[33] Republic, *Operation, Maintenance, and Monitoring Plan Volume 2, Gas and Subsurface Control Systems* (September 2013).

[34] Republic, *Bridgeton Landfill North Quarry Contingency Plan – Part 1* (August, 2013), at p. 14.

[35] Republic, *Monthly Gas Well Temperature Reports to MDNR* (September 2012 to October 2013).

[36] Republic, *Monthly Gas Well Temperature Reports to MDNR* (September 2012 to October 2013).

[37] MDNR Website: Subsurface Smoldering Event - Bridgeton Sanitary Landfill http://www.dnr.mo.gov/env/swmp/facilities/BridgetonSanitaryLandfill-SSE.htm

[38] The chart is calculated using EPA's Landgem model of first order decay in which new wastes ceased in 2004.

[39] Patrick Foss-Smith, "Understanding landfill fires," *Waste Management World* (August 2010

[40] Republic, *Bridgeton Landfill North Quarry Contingency Plan – Part 1* (May 13, 2013), at p. 6.

[41] Patrick Foss-Smith, "Investigation Into the Initiation, Detection, Treatment and Prevention of Landfill and Tyre Fires," Dissertation (U. Southhampton, 2010), at p. 21.

[42] Craig Beyler, *Thermal Decomposition of Polymers* SFPE Handbook (2002).

43 Charles Wilkes, *PVC Handbook* (2005), at p. 414.

44 Republic, *Bridgeton Landfill North Quarry Action Plan – January 2014 Revision*, at p. 5.

45 Under pressure from MDNR, Republic now states that it plans to take limited carbon monoxide readings and add three TMP wells. Republic, *Bridgeton Landfill North Quarry Action Plan* (January 2014) *3rd Revision* (Third North Quarry Action Plan), at p. 5.

46 Republic, *North Quarry Contingency Plan – Part 1* (August 13, 2013), at Figure 2 on PDF p. 475. Peak temperatures during the prior year are overlain on the map from the weekly and monthly reports to MDNR by Republic for the GEW and TMP wells shown, and, as before, the GEW readings were normalized by 10% to reflect the fact that those wells understate temperatures by averaging the gas in the entire well.

47 Republic, North Quarry Action Plan (January 18, 2014 Revision), at Appendix C.

48 MDNR Website Site: Background – Bridgeton Sanitary Landfill, on-line at http://www.dnr.mo.gov/env/swmp/facilities/BridgetonSanitaryLandfill-Background.htm.

49 *Thalhammer Report*, at pp. 4-5.

50 Eugene Meyer, *Chemistry of Hazardous Materials* 5th Ed. (Brady Publishing, 1977).

51 Bob Downing, "Little evidence that fires are slowing at Stark landfill," *Beacon Journal* (January 10, 2013).

52 *Supplemental Feasibility*, at pp. 8-9.

53 Meyer, *op. cit*.

54 Republic, *Laboratory Analysis and Maximum Initial Temperatures at Bridgeton Landfill* (February 20, 2014).

55 *Thalhammer Memorandum*, at pp. 7 to 8.

56 H.A. Mohamad Puad, M.Y. Muhd Noor, "Behaviors of 323Th, 238U, 228Ra and 226Ra on combustion of crude oil terminal sludge," 73 *J. of Env. Radioactivity* 289-305 (2004), at p. 289.

57 *Id.*

58 *Alverez Report,* at p. 4.

59 Y. Zhang Y, "Corrected Values for Boiling Points and Enthalpies of Vaporization of Elements in Handbooks" 56 *J. Chem. Eng. Data* 328–337 (2011).

60 H.A. Mohamad Puad, M.Y. Muhd Noor, "Behaviors of 323Th, 238U, 228Ra and 226Ra on combustion of crude oil terminal sludge," 73 *J. of Env. Radioactivity* 289-305 (2004) (Puad and Noor Study), at TABLE 4 p. 294.

61 Bob Downing, "Little evidence that fires are slowing at Stark landfill," *Beacon Journal* (January 10, 2013).

70 Patrick Foss-Smith, *Investigation into The Initiation, Detection, Treatment and Prevention Of Landfill and Tyre Fires* (Dissertation, University of Southampton School of Civil Engineering and the Environment, 2010) (Foss-Smith Dissertation), at p. 21.

71 EMSI, *Groundwater Monitoring Report 2012 Additional Groundwater Sampling Event West Lake Landfill Operable Unit-1* (December 24, 2012), at FIGURE 8; EMSI, *Groundwater Monitoring Report April 2013 Additional Groundwater Sampling Event West Lake Landfill Operable Unit-1* (July 8, 2013), at FIGURE 7.

72 Department of Energy, *Primer on Spontaneous Heating and Pyrophoricity* (DOE FSC-6910)(1994), at p. 19.

73 Tchobanoglous, *op. cit.,* at p. 281.

74 EPA Landgem Model (2014). The model was run with 278,020 tons received annually between 1995 and 2004.

75 Gregory N. Richardson, "Active LFG control: An unreliable aid to veneer stability," *Geosynthetics* (June 2008)

76 Tchobanoglous, *op. cit.,* at pp. 72-73 and 393.

77 *Foss-Smith Dissertation*, at p. 14.

78 MDNR Website: Construction Schedule – Bridgeton Sanitary Landfill, on line at: http://www.dnr.mo.gov/env/swmp/facilities/BridgetonSanitaryLandfill-Construction.htm.

79 R. M. Frost, *Nuclear Terrorism After 9/11*, Roundtable for The International Institute for Strategic Studies (2005).

80 Donald Ermak, "An analytical model for air pollutant transport and deposition from a point source," 11 *Atmospheric Environment* 3 (1977), at p, 231.

81 Susan Thornloe, *Innovative Air Monitoring at Landfills Using Optical Remote Sensing with Radial Plume Mapping* (EPA/NRMRL, February 22, 2007), at 4.

82 XXX

83 Republic, *Operation, Maintenance and Monitoring Plan Part II – Gas and Subsurface Control Systems* (September 2013), FIGURE 1 at PDF p. 26.

84 *Second North Quarry Action Plan*, at PDF p. 75.

85 Environmental Protection Agency (Irish) Office of Environmental Enforcement, *Guidance Note on Landfill Flare and Engine Management and Monitoring* (2012), at p. 5.

86 Missouri DNR Website, Bridgeton Landfill, Construction Schedules (accessed February 9, 2014).

87 *Thalhammer Report*, at p. 3.

88 Republic, *Monthly Data Submittal* (December 20, 2013), Settlement from 11/18/13 to 12/19/13, at PDF p. 36.

89 See, Republic, *Monthly Data Submittal* (December 20, 2013), Settlement from 11/18/13 to 12/19/13, at PDF p. 36.

90 *Thalhammer Report*, at p. 2.

91 Hammer Consulting Service, *Data Evaluation of the Subsurface Smoldering Event at the Bridgeton Landfill* (June 13, 2013), at p. 14.

92 P. M. Czepiel, et al., "Quantifying the effect of oxidation on landfill methane emissions," *Journal of Geophysical Research* (July, 20, 1996)., at p. 16,727.

93 Stephen Whitt, "Lighter than Air," 38 *Cricket* 6 (March 2011), at p. 34.

94 EPA, *Radiation Protection: Alpha Particles: The Basics*, on line accessed March 1, 2014 at: http://www.epa.gov/radiation/understand/alpha.html.

95 *Alverez Report*, at p. 4.

96 St. Louis Sites Remediaion Task Force, *The History of the St. Louis Uranium Processing Radioactive Waste Sites* (1996), at p. 17.

97 Agency for Toxic Substances and Disease Registry (ATSDR), *Public Health Statement for Radium* (December 1990), at p. 2.

98 George Voelz, "Plutonium and Health, How Great is the Risk," 26 *Los Alamos Science* (2000) 74, at p. 78.

99 ATSDR, *op. cit.*, at p. 3.

100 D. Brugge, "Radium in the environment: exposure pathways and health effects," 27 *Rev Environ Health* 1 (2012), at p. 5.

101 EMSI, *Evaluation of Possible Impacts of a Potential Subsurface Smoldering Event on the Record of Decision – Selected Remedy for Operable Unit-1 at the West Lake Landfill* (January 14, 2014) (Possible Impacts Evaluation), at p. 11.

102 Department of Health and Senior Services, *Review of Comprehensive Air Sampling Data for 4/16/13, 5/07/13 and 5/08/13* (June 17, 2013); MDNR Website MDNR Website: Odors – Bridgeton Sanitary Landfill, on line at: http://www.dnr.mo.gov/env/swmp/facilities/BridgetonSanitaryLandfill-Odors.htm, and data sets compiled.

103 Department of Energy, *Primer on Spontaneous Heating and Pyrophoricity* (DOE FSC-6910)(1994), at p. 19.

104 *Possible Impacts Evaluation*, at pp. 11-12.

105 *Criss Report*, at p. 5; *Alverez Report*, at p. 4.

106 *Possible Impacts Evaluation*, at p. 2 ff.

107 Y. Zhang Y, "Corrected Values for Boiling Points and Enthalpies of Vaporization of Elements in Handbooks" 56 *J. Chem. Eng. Data* 328–337 (2011).

108 Puad and Noor Study, at TABLE 4.

109 Foss-Smith Dissertation, at p. 21.

110 *Id.*, at p. 4.

111 Foss-Smith Dissertation, at p. 21.

112 *Id.*, at pp. 14-15.

113 *Possible Impacts Evaluation*, at p. 12.

114 *Id*., at p. 10.

115 Missouri DNR Website, Bridgeton Landfill, Homepage (accessed February 9, 2014).

116 Republic, *Bridgeton Landfill – North Quarry Action Plan* (Rev. November 12, 2014), at p. 2.

117 Tchobanoglous, *op. cit*., at p. 385.

118 56 FED. REG. 24473 (May 30, 1991); EPA, *Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities* (EPA-600/R-05/123a, 2005), at p. 2-4; George Tchobanoglous, *Integrated Solid Waste Management* (McGraw-Hill, 1993), at p. 384.

119 EPA, *AP-42 Compilation of Air Pollutant Emissions Factors – 2.4 Municipal Solid Waste Landfills* (2008), at p. 2.4-3.

120 H.A. Mohamad Puad, M.Y. Muhd Noor, "Behaviors of 323Th, 238U, 228Ra and 226Ra on combustion of crude oil terminal sludge," 73 *J. of Env. Radioactivity* 289-305 (2004) (Puad Study), at p. 289.

121 Gregory N. Richardson, "Active LFG control: An unreliable aid to veneer stability," *Geosynthetics* (June 2008).

122 Tchobanoglous, *op cit*., at p. 406.

123 40 C.F.R. §60.753(c).

124 Intergovernmental Panel on Climate Change, *Fourth Assessment Report Waste Chapter 10* (2007), at p. 600, which states landfill gas collection capture rates are "as low as 20%." Very briefly, the reason for the inherent poor performance of landfill gas collection is due to the fact that, on the one hand, the systems only function properly after a low-permeable final cover has been installed. Otherwise, the negative pressures used to extract landfill gas will also pull oxygen from the surface that is explosive when mixed with methane, short-circuting the system. Yet, after the final cover is installed, precipitation no long infiltrates the waste mass, and without that additional moisture, gas generation slows and the site goes dormant, becoming the proverbial "dry tomb." Therefore, when most of the gas is generated, gas collection is dysfunctional, and only when little gas is created is there functioning gas collection. *Id.*

125 The reason why gas collection at Bridgeton will always remain badly impaired, no matter how aggressive the efforts for improvement, is because, in addition to the further complications created by the fire, high moisture conditions in the unlined landfill in the Missouri River flood plain are incompatible with reliable gas capture. Also, the cover, on which gas collection depends to create a seal and minimize oxygen infiltration, will be subject to continuing stresses from the voids created by the fire.

High moisture conditions obstruct gas capture. The abnormally high moisture conditions in the landfill will obstruct gas collection for several reasons.

In the high water table conditions that recur at the bend of the Missouri River, the perforated vertical gas collection wells will often flood out. Even under normal non-flood water conditions, landfills in general, and West Lake/Bridgeton in particular, have pools of perched water above the base of the landfill, which also flood the gas wells and impede gas flows to the collection pipes. The addition of the underground fire, whose heat front vaporizes moisture, which condenses further ahead of the front, creates localized areas of even greater saturation. *Foss-Smith Dissertation*, at p. 14. Republic's records shows that in 2013 two-thirds of the wells were flooded in part, with only an average of 60% of the well's perforated span not flooded. *North Quarry Action Plan*,

Bridgeton GCCS Evaluation 9/25/13), at PDF p. 81.

Also, under normal conditions, we estimate that the Bridgeton Landfill experiences about six times the leachate generation of a compliant landfill. See NOTE 144. Those leachate volumes strongly suggest saturated conditions in the waste mass, which are antagonistic to the ready flow of gas through the waste mass. Consequently the capacity of the vacuum pressures in the wells to draw in gas from the zone of influence around the pipe will be reduced as much as 1,000 times. L. Lung-Yu Chen, "Binary Gas Diffusion of Methane and Nitrogen Through Three Porous Solids," 23 *AIChE Journal* 3 (May 1977), at 336.

This problem can be seen in the fact that once a compliant landfills is finally closed with a composite cap, it is usually able to control odor and oxygen infiltration problems with gas wells 350 feet apart. Gas well density at Bridgeton's North Quarry appears to be about 150 feet or less apart, Republic, As Built Site Infrastructure Plan (December 31, 2013). yet, the operator still continues wrestling with significant odor complaints, Missouri DNR Website, Bridgeton Landfill, Home Page, Odor Complaints (accessed February 9, 2014), overinflated cover problems, *Thalhammer Report*, at p. 2, and subsurface lateral methane migration, Republic, *Monthly Data Submittals* (December 20, 2013), Gas Monitoring Probe Data (wells 1, 2, 3, 5S, 14D and 14S. Also, oxygen levels in the consolidated gas lines, which should be significantly less than 5%, 40 C.F.R. §60.753(c). are deteriorating. Since this past summer, when O_2 levels tended below that threshold, infiltrating oxygen trended above 10% by the end of 2013, and presumably is worse in gas lines closer to the fire.

To a certain extent, these conditions have been exacerbated by the fire. Republic, *Bridgeton Landfill – North Quarry Contingency Plan Part 1* (August 2013), at p. 5. Indeed some of the gas problems that Republic is experiencing are unique to a fire situation such as the marked changes in the quantify and composition of the landfill gas of which 98% of the non-radioactive hazardous air pollutants is supposed to be destroyed in the flare. North Quarry Action Plan, at p. 3-4. But, on the other hand, the odor and methane migration problems, which are key indicators of gas collection deficiencies, predated the fire. Jeffrey Tomich, "Records show history of methane violations at Bridgeton Landfill," *St. Louis Post Dispatch* (July 20, 2013).

Adding wells increases leaks. Increasing the number of gas extraction wells as an effort to address persistent odor problems, ironically, also increases the number of escape routes, which worsens further over time as subsidence increases.

Bridgeton has no liner to prevent gas outflows or groundwater inflows, and that, among other things, substantially increases gas generation, odors and subsurface methane migration. To reduce those odors and gas migration, more gas collection wells have and continue to be ordered. Unfortunately, as another irony, because the well heads themselves provide a new route for gas to escape, the more wells that are drilled, the more places there are for gas to escape from as the landfill subsides. The presence of the underground fire magnifies this vicious spiral, as it both increases the odors and emissions that compel more wells, as it also creates significantly greater subsidence that adds more escape routes.

For cracks routinely occur in broken seals in the bentonite plug that closes off the annulus between the cover and the gas collection pipes around the well head. This is where a hole is deliberately cut into the plastic cover so the well head at the surface to carry off the gas to the flare can connect to the collection pipe that is drilled below through the wastes. Global Methane Initiative, *International Best Practices Guide for LFGE Projects* (2012), at p. 22.

Worse here, because of the large voids created by the underground fire at Bridgeton, there are more subsidence problems, cracked seals and routes for gases to be released. Moreover, the intertwined problems collapse in on themselves in a vicious cycle. As pipe seals weaken, not only will more radiotoxins, other hazardous compounds and odors escape. At the same time, more unwelcome oxygen will be pulled into the waste mass, exacerbating the same fire that originally worsened the cracks in the seals.

All that is not necessarily meant to suggest that more gas wells should not be ordered, as EPA's rules require

when leaks persist. 40 C.F.R §60.755(c)(4)(v). Rather, the takeaway point is that the flaws in this landfill's siting and design are so fatal that much of what must be done to overcome the resulting problems will aggravate other issues. That significant potential for counterproductive unintended consequences must always be factored into regulatory decision making.

Deep wells are marginally effective at depth. The Bridgeton landfill is sited in extremely deep abandoned limestone quarries, which degrades overall gas collection further because of the extreme difficult pulling gas at great depths.

At its maximum extent, Bridgeton is an unusual 340 feet deep. Other than canyon landfills, few landfills are 300 feet deep, and more large landfills are about 200 feet deep. EPA, Landfill Methane Data Base (2013). That extreme depth impedes gas collection.

For the ability of the negative pressures exerted through the perforated gas wells to reach out from the pipe to pull gas is a function of its particle size and the compression ratio of the wastes, or the porosity of garbage. At greater depths the compression from the overburden increases, porosity decreases and the lateral reach of the vacuum pressures from the gas wells tapers off quickly. Sometimes, well constructed landfills attempt to offset this problem by inserting three different pipes into a single casement, with each one exerting greater negative pressures at each deeper region. But that has not been commonly done at Bridgeton. International Solid Waste Association, *Field Procedures Handbook For The Operation Of Landfill Biogas Systems* (2005), at Exhibt 5-2.

Consequently, by the company's own admission, Republic, *Bridgeton Landfill – North Quarry Contingency Plan Part 1* (August 2013), at p. 5, the gas well's radius of influence in its lower reaches of the especially deep landfill is marginal at best.

Stresses degrade cover performance. Initially, according to complaints that date back to the late 1990s, the operators were unable to control odors or subsurface methane migration into adjoining buildings. This was largely because there was no compliant low permeable cover on top of the landfill to prevent the system from also pulling oxygen from the surface at flammable levels when mixed with the methane in the landfill gas, nor liners to block migration. Jeffrey Tomich, "Records show history of methane violations at Bridgeton Landfill," *St. Louis Post Dispatch* (July 20, 2013).

By 2006, with public complaints increasing, and regulators demanding compliance, Bridgeton's operators pulled as hard as they could on the gas wells. *Id.* In the process, they ignored the alarm bells raised by infiltrating oxygen. *Thalhammer Report*, at p. 18. and soon, in our opinion, they caused the subsurface fire that, since the end of 2012, has been volatizing the radiotoxins dispersed throughout the landfill.

In the last year and in response to the significant risks created by the underground fire, MDNR ordered installation of a ultra-low permeable geomembrane to impede emissions out, as well as to reduce oxygen infiltration into the landfill. Otherwise, gas collection and control over the fire would be seriously complicated. The cover of the South Quarry was completed in October, 2013, and construction of the North Quarry cover continues at this writing. Missouri DNR Website, Bridgeton Landfill, Construction Schedules (accessed February 9, 2014).

Unfortunately, because of the wastes consumed by the underground fire, which has led to voids below, there has been major subsidence of 15 to 20 feet at the surface during the two year period the underground fire took hold. See the map in FIGURE 30. *Thalhammer Report*, at p. 3. Republic's most recent monthly report for YE2013 continued to show subsidence of as much as 5 feet in one month. Thalhammer Report, at p. 3.

As the underground fire causes the ground under the cover continues to subside, see, Republic, *Monthly Data Submittal* (December 20, 2013), Settlement from 11/18/13 to 12/19/13, at PDF p. 36. the new multi-layer cover will tear and degrade to the point it can no longer be patched or perform, but instead will require continued

expensive replacement. Until and unless, the leaks are detected, and patching and replacement is done, landfill gas will escape out the cracks in the new cover. *Thalhammer Report*, at p. 2.

Clearly, remedies should not be directed without first attempting to balance all of the confounding factors, in full knowledge that our capacity to tease out accurate predictions of how all these interactions will play out, as well as the many unknowns, is limited. Most important, for these reasons, regulators should not delude themselves that the situation can be brought under control until the underground fire burns itself out, which could be ten or 20 years from now.

Finally, in addition to the new cover's limited life, the surface of the landfill is not the only route for radioactivity to be released into the environment.

126 58 FED. REG. 56, 24468, at 22474 (May 30, 1991). There are significant concerns about dioxin formation in shrouded flares where temperatures slightly cool, EPA, *Dioxin Reassessment, Estimating Exposure to Dioxin-Like Compounds*, Volume 2, Chapter 3 (1994), but those are outside of the issues dealt with in this report.

127 40 C.F.R. §60.18(b).

128 Air & Waste Management Association, *Air Pollution Engineering Manual* (Van Nostrand Reinhold, 1992).

129 40 C.F.R. §60.752(b)(2)(iii).

130 Dr. Mohamed Khallaf (ed), *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources* (InTech, 2011), at 332.

131 EPA, *Dioxin Reassessment, Estimating Exposure to Dioxin-Like Compounds* (1994), at Volume 2, Chapter 3.

132 G. T. Emery, "Perturbation of Nuclear Decay Rates," *Annual Review of Nuclear Science* 22 (1972), at p.165. (1972).

133 Lars Rydén, *Environmental Engineering and the Technology of Clean Air* (2010), at p. 489.

134 *State of Missouri v. Republic Services* (Case 13-SC-CC01088), Plaintiff's Application for Further Relief Under First Agreed Order (January 9, 2014).

135 40 C.F.R. §258.1(e).

136 40 C.F.R. §§258.11, 258.40(a)(2) and 258.60(a).

137 *ROD*, at p. 8.

138 Hazardous and Solid Waste Amendments of 1984 to the Resource Conservation Recovery Act of 1976, 42 U.S.C. §§6901-6992.

139 John Miller, "Budget cuts imperil environmental programs, along with health and safety," Associated Press (November 27, 2011); Willem H. Buiter, "Central banks and financial crises," Speech to the Federal Reserve Board's Annual Symposium at Jackson's Hole (August 23, 2008).

140 Republic, *Operation, Maintenance, and Monitoring Plan, Volume 2, Gas and Subsurface Control Systems* (September 2013), FIGURE 1, at PDF p. 16.

141 *Leachate Plan*, at p. 3.

142 Tchobanoglous, *op. cit.,* at p. 421.

143 *Leachate Plan*, at p. 2.

144 Our estimate was calculated as follows –

ESTIMATE OF LEACHATE FROM SIMILAR CONFORMING SITE

Cumulative Rain	**27,154**	**gallons/acre/inch**	**/1**
Size of Bridgeton LF	**52**	**acres**	
St Louis Precipitation	**37.54**	**inches/year**	
Infiltration	**30%**		
	15,902,034	**gallons leachate/year**	
	43,567	**gallons leachate/day**	

1/ USGS, Water Science, Amount of Rain When an Inch of Rain Falls (2013).

145 *Leachate Plan*, at p. 1.

146 *Thalhammer Report*, at p. 21.

147 *Id*., at p. 18.

148 See discussion of volatilzation of radium and thorium isotopes on page 25.

149 *ROD*, at p. 19.

150 Republic, *Revised Interim Leachate Management Plan* (December 18, 2013), at p. 1 and 7.

151 Patrick Foss-Smith Investigation into the Initiation, Detection, Treatment and Prevention Of Landfill and Tyre Fires (Dissertation University of South Hampton, 2010), at p. 8.

152 Compare Republic, Excel Spreadsheet of Leachate Radiation Levels, provided by MDNR under OR25387 Open Records Request (January 9, 2013) (Leachate Spreadsheet) to Republic, Monthly Reports to MDNR Under First Agreed Order.

153 Republic, Monthly Reports to MDNR Under First Agreed Order (2/14/14),

154 *Leachate Spreadsheet*.

155 Letter from John Frazier to Barr Engineering, dated June 25, 2013, and Attachment.

156 Republic, *Bridgeton Landfill – Revised North Quarry Action Plan* (November 12, 2013), at FIGURE 2.

157 Open Records Request OR25387.

158 Letter dated June 25, 2013 from John Frazier to Barr Engineering re Review of Laboratory Analytical Results of Leachate Sample.

159 Personal communication with Dr. Robert Criss, January 23, 2014.

160 Republic, Bridgeton Landfill North Quarry Action Plan (November 12, 2013) (Second North Quarry Action Plan), at Sheet 3, at PDF p. 42.

161 *Leachate Plan*, at p. 4.

162 *Leachate Plan*, at pp. 1 and 5 to 6.

163 Jianguo Zhang, "Research on the Removal of Radium from Uranium Effluent By Air-aeration Hydrated Manganese Hydroxide Adsorption" (International Atomic Energy Agency, 2003), at p. 93.

164 40 C.F.R. §258.40(a)(2).

165 Wisconsin Department of Natural Resources, Survey of Regional Offices LCS History (2004).

166 40 C.F.R. §258.40(a)(2).

167 Republic, Monthly Data Submittal, Leachate Level in Leachate Collection Sump Raw Data (1/28/14).

168 Republic, Leachate Level in Leachate Collection Sump Raw Data (1/28/14), at PDF p. 10.

169 Republic, *Bridgeton Landfill North Quarry Contingency Plan – Part 1* (August 2013).

170 *Id*., at FIGURE 3 at PDF p. 14.

171 West Lake Landfill OU-1 Respondents, *Supplementary Feasibility Study*, dated December 28, 2013.

172 West Lake Landfill OU-1 Respondents, *Remedial Investigation Report*, dated April 10, 2000.

173 Republic, *Bridgeton Landfill North Quarry Action Plan* (October 7, 2013), at FIGURE 2 on PDF p. 17.

174 *Criss Report*, at p. 6.

175 West Lake Landfill OU-1 Respondents, *Remedial Investigation Report* (2000), at FIGURE 5-3 on PDF p. 247.

176 West Lake Landfill OU-1 Respondents, *Remedial Investigation Report*, dated April 10, 2000, at FIGURE 5-3 PDF p. 247.

177 *Thalhamer Report*, at p. 20.

178 Memorandum from MDNR Consultant Todd Thalhamer, P.E. and Timothy Stark, Ph.D., P.E., D.GE, re: Comments on the Draft Bridgeton Landfill North Quarry Contingency Plan – Part 1, dated July 22, 2013, at p. 7.

179 *Puad Study*, at p. 289.

180 Republic, *Bridgeton Landfill – North Quarry Contingency Plan* – Part 1 (June 27, 2013) at p. 13.

181 Republic, *Gamma Cone Test Work Plan Revision 2* (September 27, 2013).

182 Republic, *West Lake Coring (Phase 1B, 1C and 2) Work Plan* (Revisions dated January 8, February 11 and February 27, 2014; EPA7, *West Lake Updates* (February 27, March 5 and March 16, 2014).

183 *Thalhammer Memorandum*, at pp. 8-9.

184 *Alverez Report*, at p. 1.

185 *State of Missouri v. Republic Services*, Case 13SL-CC01108, First Agreed Order of Preliminary Injunction (May 14, 2013), at ¶41, p. 19.

186 Mo. Rev. Statues 260.227.1.

187 Mo. Rev. Statues 260.227.8.

188 Memorandum from Randal Bodner to Bridgeton Landfill dated May 30, 2013, re Financial Cost Estimates (Financial Assurance Memorandum), at p. 2.

189 *First Agreed Order*, at ¶25 on p. 13.

190 *Financial Assurance Memorandum*, at p. 7.

191 SEC, Republic Form 10-Q for 2nd Quarter 2013.

192 Michael de la Merced, "Waste Firms Set Merger for $6 Billion," *NYTimes* (June 24, 2008). *U.S. v. Republic*, Final Judgment, Civil Action No.: 1:08-CV-02076 (D.C.D.C. July 15, 2010).

193 SEC, Republic Form 10-Q for YE 2013, at p. 94.

194 11 U.S.C. §§ 1101-1174.

195 Joel Millman, "Asarco Bankruptcy Leaves Many Towns with Cleanup Mess," *Wall Street Journal* (May 24, 2006); Elisabeth Malkin, "Asarco Settles with Justice Dept. on Sale and Pollution," *NYTimes* (February. 4, 2006).

196 Sammy Fretwell, "Landfill deal threatens S.C. lake, taxpayers," *The State* (June 13, 2004). Ten years later, the paper reported that the state is running out of money to monitor for leaks, because the settlement had been inadequate providing only $1 million annually for maintenance that has actually exceeded $4 million. All that is before the bill comes due to remediate the leaking site. Sammy Fretwell, "Funds drying up to check for toxic leaks near Lake Marion," *The State* (January 8, 2014).

197 *In re Dow Corning Corp*., 456 F. 3rd 668 (6th Cir. 2006).

198 *In re AMR Corp*., (Bankr. S.D.N.Y. Jan. 17, 2013).

199 11 U.S.C. §§ 362(b)(4).

200 *U.S. v. Johns-Manville,* 18 Env. Rpt. 1177 (D. N.H. 1982)

201 *MidAtlantic v. N.J. Dept Env. Prot*. 474 U.S. 494 (1986).

202 *N.M.Env. Dept. v. Foulston*, 4 F.3rd 887 (10th Cir. 1993).

203 *In re Smith Douglass*, 846 F.2nd 17 (4th Cir. 1988).

204 *Penn. Dept. Env. Res. v. Conroy*, 24 F. 3rd 568 (3rd Cir. 1994).

205 11 U.S.C. §1141(a)(1)(A).

206 *Chateaugay I*, 944 F. 2nd 997 (2nd Cir. 1991).

207 *Am Int'l*, 106 F. 3rd 1342 (7th Cir. 1997).;

208 *Chateaugay I*, 944 F. 2nd 997, 1008 (2nd Cir. 1991)

209 42 U.S.C. §9607.

210 42 U.S.C. §§6901 to 6992.

211 10 CSR §25.

212 11 U.S.C. §1129(b)(3).

213 SEC, Republic Form 10-Q for YE 2013, at pp. 26 and 55.

214 Mari Bari, *Waste Management: Getting Focused on the Long-Term Big Picture Cash-Flow Story*, (Duetsche Bank, 1999).

215 Mo. Rev. Stats. §260.249; 10 CSR 80-2.040.

216 Mo. Rev. Stats. §260.240.

217 40 C.F.R. Part 300.

218 Conn. Gen. Stat. 22a-452a; 415 ILCS 5/21.3; La. Rev. Stat. Ann. § 30:2281; Me. Stat. Ann. tit. 38, sect. 1370, 1306-C, 1362; Mass. Ann. Laws ch. 21E, sec. 13; Mich. Comp. Laws Ann. 324.20138; N.H. Rev. Stat Ann. § 147-B:10-b.