Water Contamination and Land Prices in a Mountainous Landscape

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Abstract:

In a mountainous terrain surface water contamination relates to stream flow and topography, while shallow and deep groundwater contamination flow depends on fissures in bedrock which can only be detected and predicted using a variety of complex methods. Using data from western North Carolina, we examine how the risk of offsite water contamination from an inactive hazardous waste site is capitalized into local property values. Offsite surface and groundwater contamination took place over a 12-year period until the site was eventually placed on the National Priority List. Our findings suggest that shallow groundwater contamination risk is capitalized into land prices but that deep groundwater threats are not. This last result suggests that better information concerning potential deep groundwater contamination flow might be necessary. Finally, the length of time between the end of on-site contamination and the detection of off-site contamination was longer than the statute of repose in North Carolina, suggesting that in a mountainous terrain the current statute's horizon may be too short.

INTRODUCTION

A Superfund site is a hazardous waste site which has extensive enough contamination that the U. S. Environmental Protection Agency (EPA) either cleans the site itself or requires parties responsible for the contamination to do so. The Superfund program was established after the discovery of several toxic waste sites across the United States during the 1970s and was created by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA U.S. 42 § 9601). As of January 2014 there were over one thousand Superfund sites on the EPA's National Priorities List (see EPA 2014).

In this study we examine the effect of water contamination from a former manufacturing site on vacant land prices. Located near Asheville, NC, the site housed a series of firms that, over several decades, engaged in electroplating as part of their manufacturing process. The solvent trichloroethylene (TCE) is the main contaminant at the site. TCE is associated with various adverse health consequences, including cardiac and neurological problems and liver damage. The site remained the responsibility of the state of North Carolina until March, 2012, when it was designated a Superfund site by the Environmental Protection Agency.

While there is a large literature relating to Superfund sites and property values, in this paper we focus on measuring any price effects from the discovery of off-site water contamination, where this discovery predates the later Superfund designation date by twelve years. We are also the first to separately estimate the impact of potential contamination to both surface water and shallow and deep groundwater. Identifying potential groundwater contamination, which is related to the surrounding mountainous terrain and geology, is an important empirical test of how information is capitalized in a property market.

We model the effect of water contamination several ways in the context of a hedonic framework. Because the study area is mountainous with various stream networks, we control for stream presence and stream flow, among other factors. The contamination site is located in the headwaters of two streams. Accordingly, only those properties downstream from the contamination source should be prone to surface water contamination. To proxy shallow and deep groundwater contamination we using geologic surveys the EPA conducted of the geologic layers underlying and surrounding the site.

Our empirical analysis indicates that water flow and topography are factors which are considered in land-market participants pricing of water contamination risk. Using various measures of distance from the contamination site, we find that prior to contamination the site was in a localized value peak. We find little evidence that potential contamination to surface water influences property values in this market. However, we find strong evidence that potential shallow groundwater contamination has a strong negative influence on property values. Finally, we find no evidence that potential deep groundwater contamination has an influence on property values, even though deep groundwater contamination might pose the greatest long-term risk to drinking water supplies. Our findings have implications for measuring third party claims associated with hazardous waste sites and to the appropriate length of time associated with any statute of repose in mountainous terrain.

LITERATURE

In most studies relating property values to environmental contamination, hedonic pricing methodology is used to measure the effect of the initial discovery of contamination, the EPA's NPL designation, and/or the associated clean up at a Superfund site.[1] The first study to measure the effect of the NPL designation was Kohlhase (1991) who examines property values near multiple hazardous waste sites in the Houston, TX area that were eventually placed on the NPL. She finds property values near the sites decline only after the NPL listing. However, the finding that these declines reversed at one site after cleanup suggests that such effects may not be permanent. Kohlhase, Michaels, and Smith (1990) examine properties near hazardous waste sites in the Boston area, some of which were on the NPL. While their results vary by submarket, in general they find evidence that house prices increase with distance from a site. Mendelsohn, et al. (1992) use a repeat-sales methodology to examine a site contaminated with PCB in New Bedford, MA and find negative price effects associated with the site before it was proposed to the NPL. Kiel (1995) is the first in this literature to examine the price effects of hazardous waste sites using a sample period that includes discovery of contamination, NPL listing, and clean up. Using data from Woburn, MA, where two NPL sites are located, Kiel finds no adverse price effects associated with the sites until discovery of contamination. After discovery, but before the NPL listing of the sites three years later, price effects from contamination were partially capitalized in the housing market. Further

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[1] See Boyle and Kiel (2001) for a general review of hedonic studies on environmental contamination.

capitalization occurred with the listing. Unlike Kohlhase (1991), Kiel finds no effect of EPA clean-up announcements on property values in the area.[2]

Dale, et al. (1999) examine property values near a lead smelter in Dallas, TX, which was initially declared to be clean but eventually landed on the NPL. They find the market generally capitalized negative externalities from the site before information about soil contamination and potential health risks were known. Like Kohlhase (1991), Dale, et al. find property values rebound after the initial clean-up (which at the time was thought to have been successful). Gayer, et al. (2002) study Superfund sites in the Grand Rapids, MI area between 1988 and 1993. The sample period begins before any public health risks associated with the sites are publicized and ends after the EPA declares the site to be clean. They find the willingness-to-pay by residents to avoid the risks associated with these sites decreases after the EPA's NPL designation, suggesting the public perceives lower levels of risk following the designation.

There are several studies that examine the price effects of water contamination but are independent of any Superfund designation. McLaughlin (2011) tests the house price effects of varying levels of public information about water contamination, from rumors to actual media coverage, in Washington County, MN. McLaughlin uses both distance from the contaminated site and actual ground tests, and finds "at risk" houses suffered no greater loss in value than those properties that were not at risk. Michael, Boyle, and Bouchard (1996) use turbidity to measure the impact of water contamination on housing prices.[3] They find that water clarity significantly and positively affects land prices around Maine lakes. Finally, Epp and Al-Ani (1979) examine residential sales near small rivers

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[2] Kiel and Zabel (2001) use hedonic valuation to estimate the willingness to pay to clean up the same sites examined by Kiel (1995).

[3] Turbidity measures particulates in water and is a standard measure of water quality.

and streams in Pennsylvania. Using both an index of water quality characteristics, as well as owners' perceptions of water quality, they find that water quality positively affects the value of property adjacent to streams.

BACKGROUND

The NPL Superfund site that is the basis for this study is located about five miles outside of Asheville, NC, in an area known as Skyland. From 1952 to 1986 the site housed various entities that engaged in electroplating at the site, or the use of electricity to coat solid surfaces with metals dissolved in water (see Paunovic and Schelsinger 2006).[4] As part of this process, parts were washed with TCE prior to electroplating with tin, nickel, zinc, and silver. This contaminant was washed off during the electroplating process and released from the building via drains in the facility, a one-story building located in the northeast corner of the site.[5]

The site has a long history of environmental inspections. In 1984, during a Resource Conservation and Recovery Act compliance inspection, the North Carolina Solid and Hazardous Waste Management Branch found noncompliance in several areas, including the accumulation time of hazardous waste at the facility.[6] In 1985, the North Carolina Department of Human Resources (NCDHR) conducted a preliminary assessment of the site, but it was given a low priority recommendation.[7] In 1987, the site owner hired a consultant to provide an assessment of the actual and potential

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[4] US Environmental Protection Agency 2011 pg. 15.

[5] Ibid.

[6] Ibid p.16

[7] Ibid.

environmental liabilities associated with the property.[8] Between 1989 and 1991, an EPA subcontractor took part in a two-phase screening site inspection (SSI). The substances vinyl chloride, TCE, and 1,2-dichloroethene were detected in soil, sediment, and surface water samples at the site. However no further remedial action was recommended to the owner.[9]

The first official instance of offsite water contamination occurred in July of 1999, when the North Carolina Department of Environment and Natural Resources (NCDENR) was contacted concerning oily water in a ditch on a property adjacent to the site. Samples from this site and from those of two springs on neighboring properties showed TCE and other chlorinated solvents. Residents were advised to refrain from using one spring as a water source.[10] Around this time the NCDENR found TCE in one of nine wells within a quarter mile of the site. The residents were advised not to use the well for drinking water. The NCDENR then requested a review of the property by the EPA to see whether it qualified for a removal action under Superfund.[11] In August of 1999, the EPA issued an emergency delivery order to connect four residences to the public water supply and to provide potable water as needed.[12] Additional sampling in subsequent years revealed more instances of well and surface water contamination.[13] In August of 2009, the site eventually scored high enough to be listed on the NPL. In March of 2011, the EPA proposed adding the site to the NPL, and in March of 2012 this action was finalized.

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[8] Ibid.
[9] Ibid p. 18
[10] Ibid.
[11] Ibid
[12] Ibid.
[13] Ibid pg. 19-23.

Local citizens from Asheville and Buncombe County were highly involved with the site. In 2008 a citizen monitoring group board called for both the EPA and the NCDENR to not let the previous owner go into "voluntary remediation" because taxpayers would likely bear the majority of the cleanup costs. The citizens' board stated that the county had not put adequate pressure on the federal and state governments to speed up the contamination cleanup process.[14] In May 2009, Ashville residents collected 3,100 signatures demanding "full, proper, and time-critical cleanup" of the site.[15] The group is credited with successfully lobbyig to raise North Carolina's remediation expense cap for a single responsible party from $3 million to $5 million.

Those sites on EPA's NPL are a small percentage of the country's inactive hazardous waste sites. Of the approximately 3,000 such sites in the state of North Carolina, only 34 have made the NPL. However, states have fewer resources than the EPA for environmental clean-up. As mentioned, North Carolina state law imposes a $5 million cap on remediation expenses by a single responsible party yet clean-up costs sometime run in the tens of millions of dollars. The EPA also has greater authority than do states to pursue responsible parties. In particular, CERCLA recognizes the concept of joint and several liability, meaning that any party that contributed to contamination can be held responsible as if they were the sole contributor. The EPA's greater enforcement capability provides local citizens with an incentive to obtain NPL listing for nearby sites, especially if they perceive clean-up costs will exceed the state's legal capacities or resources for clean-up.[16]

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[14] http://mountainx.com/news/040908ctssite/

[15] Ibid.

[16] Telephone conversation with Charlotte Jesneck, Branch Head, Waste Management, Superfund Section, Inactive Hazardous Sites Branch, DENR. August 16, 2013.

EMPIRICAL APPROACH

We use a hedonic pricing model to test for the effect of actual and potential water contamination on vacant land prices. We focus on vacant land sales rather than developed land sales because available transaction data on developed parcels does not provide information on property attributes (total square feet of living space, number of bathrooms, etc.). The dependent variable in the hedonic model is the sale price of a land parcel. Explanatory variables not related to contamination include lot size, lot slope, lot elevation, city, linear distance from the center of Asheville, and date of sale. These factors have been shown previously to influence vacant land prices in the Asheville, North Carolina area (see Chamblee, et al., 2009 and 2011).

The model is presented in Equation 1 below:

$$\begin{aligned}
&\ln(PRICE_i) = \beta_0 + \beta_1 \ln(ACRES_i) + \beta_2 SLOPE_i + \beta_3 ELEV_i + \beta_4 DISTHISTCBD_i + \beta_5 CITYASH_i \\
&+ DIST_i\,(\beta_6 + \beta_7 POST99_i) + STREAM_i(\beta_8 + \beta_9 POST99_i) + DOWNSTREAM_i(\beta_{10} + \beta_{11} POST99_i) \\
&+ SHALLOW(\beta_{12} + \beta_{13} POST99_i) + DEEP(\beta_{14} + \beta_{15} POST99_i) \qquad [1] \\
&+ DISTWELL99\,(\beta_{16} + \beta_{17} POST99_i) + DISTWELL08(\beta_{18} + \beta_{19} POST08_i) \\
&+ DISTWELL09\,(\beta_{20} + \beta_{21} POST09_i) + \gamma YEAR_i + u_i,
\end{aligned}$$

where the β's are parameters to be estimated and u_i is a zero-mean error term.

The explanatory variables are divided into three groups. The first group describes the physical attributes of the parcel and its location relative to the city of Asheville and the contamination site. The second group describes the surface water characteristics of the parcel, in particular whether the parcel is adjacent to streams that could have been a catchment for contaminated surface water from the site. The third group describes the groundwater characteristics of the property, in particular whether the parcel would be on top of areas in which EPA and NCDNR studies suggested would be subjected to potential shallow and deep groundwater contamination. We also control for date of sale with annual dummy variables. Finally several variables test for differences in the impact of distance from nearby well contamination sites post-discovery.

The explanatory variables include the natural log of the lot size (*LNSIZE*), the slope (*SLOPE*) and elevation (*ELEVATION*) at the parcel centroid, respectively. We expect the lot area elasticity of parcel price to be less than one, or that the coefficient β_1 is positive but less than one (Colwell and Sirmans 1993). The steeper the slope the higher will be the expected costs of any development on the parcel and thus we expect the coefficient β_2 to be negative (see Chamblee, et al. 2009). Higher elevation is often associated with better views in a mountainous landscape, and we expect better views to be associated with high land prices. On the other hand, higher elevation could indicate remoteness or more difficult access, and we might expect this to negatively influence land price though higher associated construction costs. Thus the sign of the estimated coefficient β_3 is ambiguous (see Chamblee, et. al. 2011).

The variable *DISTHISTCBD* variable is the distance from the parcel centroid to the center of Asheville’s historical central business district. We expect β_4, the estimated parameter on this variable, to be negative, indicating that land values are negatively related to distance from the center of the Asheville business district. The explanatory variable *CITYASHE* indicates whether a parcel is within the city limits of Asheville. We expect the coefficient β_5 to be positive, since land prices should increase, on net, with the added amenities provided by an Asheville location.

The main variables of interest focus on the impact of perceived contamination risk on parcel prices through the parcel's hydrological attributes and distance from the contamination site. The variable *DIST* measures the Euclidean distance of the parcel's centroid from the contamination site. The coefficient β_6 is the percentage change in price with an additional meter of distance from the contamination site. To test the effect of contamination on land prices after the contamination became public, the model includes an interaction between distance and a dummy variable, *POST99,* that takes a value of one if a sale took place after offsite contamination became public information in 1999. If there is greater benefit to being further away from the site after off-site contamination became public in 1999, we expect the coefficient β_7 to be positive.

The hydro-geologic attributes of the parcel affect the potential for contamination of both surface water and groundwater sources. In order to account for these potentials, our study includes measures of both surface water and groundwater. Surface water refers to the water that, after a rain event for instance, flow over the top of the ground and into the nearest stream. Groundwater refers to any water that, after a precipitation event, seeps into the soil, from whence it either continues flowing in line with local topography through pores in the soil back into the stream or continues flowing directly downward to reside in underlying bedrock (USGS 2014).

Surface Water Contamination

The surface-water flow process is determined by local topography and occurs over relatively short time periods (see Tague and Band, 2004). By contrast, the groundwater flow process, known as advection, is slow and more complicated, being determined by the structure of the soil or rock layers containing the water (see Fetter, 2001). This is especially true in southern Appalachia. While residence times for surface water in this region may be measured in hours to days, shallow groundwater from soils can be resident for days or months, and the deep groundwater stored in cracks may stay resident for up to 25 years or more (see Plummer et al., 2001). In order to account for these differences we have developed five variables that describe surface and groundwater flows.

To proxy for potential surface water contamination, we include an indicator variable *STREAM* that equals one if the parcel is within 100m of a perennial stream (having above-ground flow year-round). To the extent that streams provide a positive amenity of running water and other characteristics such variation in flora and fauna, we expect stream proximity to increase land values. Yet streams may be associated with greater flood risk and higher insurance costs which would represent a disamenity that would be expected to lower land values. Therefore the expected sign of the parameter on *STREAM* is ambiguous.

The contamination site is located on a ridge between two watersheds. This means that the parcels closest to the site, but still downstream of the site, are located in the headwaters of their respective watersheds. Thus, parcels can be downstream of the site without necessarily being on perennial streams because subsurface water that is resident in the soil will travel toward the perennial stream in the headwaters. The *DOWNSTREAM* dummy variable takes a value of one if the parcel is downstream from the contamination site, regardless of whether or not it is on a perennial stream. Since headwater parcels would not be adjacent to channels containing water year-round they would not have the same amenity value as those located on perennially flowing streams. However, headwater properties would still have flows in very shallow soils that would subject them to short-term groundwater contamination from the site. Therefore, the expected sign of the coefficient on DOWNSTREAM is ambiguous..

If, after public knowledge of offsite contamination, land-market participants believe that any property on a stream is at risk of surface water contamination, we would expect the coefficient on *STREAM* and its interaction with the *POST99* variable, β_9, to be negative. On the other hand, if the land market correctly prices the hydrological nature of surface water contamination, we expect β_{11}, the coefficient on the interaction of *DOWNSTREAM* and *POST99*, to be negative.

Groundwater Contamination

To capture groundwater effects beneath the soil layer, we use two variables, *SHALLOW* and *DEEP*, which distinguish between these different flows at different depths below the soil layer. These variables were developed using geologic surveys the EPA conducted of the geologic layers underlying and surrounding the site and are based on the different methods used to conduct the survey, both of which yield results that are effective at revealing the structure of geologic strata at different depths (see Chapman and Huffman, 2011:2-4).

The primary method for predicting the likely direction of groundwater contamination through subsurface flow is with a subsurface model of the contaminant plume that accounts for how the structure of the underlying geology will affect the mechanical dispersion of the contaminant (in this case TCE) that is dissolved in the groundwater (see Fetter, 2001: 402-410). These methods vary widely and depend on the chemicals involved and the nature of the subsurface geology. In the case of the site of focus in this study, the EPA determined that they would need to estimate the geographic orientation of cracks in the area's underlying bedrock in order to create the plume model (Wischkaemper, 2011).

The variable *SHALLOW* is derived from estimates of orientation of cracks in the subsurface geology that were calculated from a survey of the exposed bedrock in the area around the site. The variable *DEEP* is derived from estimates of orientation of cracks in the subsurface geology calculated from a survey of subsurface boreholes that were established in the area around the site. In each case, the calculations for orientation were obtained by counting the number of times a particular degree on the compass rose was noted during the surveys (Chapman and Huffman, 2010:7-9; Wischkaemper, 2011:14-16; see especially Wischkaemper 2011, Figures 1.9B and 1.9C). For the variables *SHALLOW* and *DEEP*, a value of one was assigned when a parcel's orientation from the contamination site fell within the orientations that were predicted more than four times by their respective survey; the variables are given a zero value otherwise.

EPA studies of shallow subsurface geology cracks predict shallower groundwater flows toward northwest and south-southeast. For those properties that fall in the shallow groundwater plumes we assign the variable *SHALLOW* a value of one, otherwise *SHALLOW* takes a value of zero. Similarly, deep groundwater flows in the study area are to the southwest and north-northeast of the contamination site. For those properties that fall in the deep groundwater plumes, we assign *DEEP* a value of one, otherwise *DEEP* takes a value of zero. Because we have no expectations concerning these flows before contamination, we expect the coefficients β_{12} and β_{14} to be equal to zero. However, once offsite contamination is discovered and the potential threat to shallow and deep groundwater is recognized, we expect that β_{13} and β_{15} may be less than zero, indicating a price discount to properties contained in the predicted flow paths.[17]

Finally, we test for whether the market responds to particular instances of off-site contamination when they are publicly announced. We measure the Euclidean distance of each parcel's centroid from three instances of private well contamination that were discovered at different times during the sample period: in 1999, 2008, and 2009. We do not expect any particular price impact before contamination was discovered and announced, and therefore we expect β_{16}, β_{18}, and β_{20} to be insignificant. However, after each contamination is made public we might expect the market to place a premium on properties that are further away from the wells. We test this by interacting each well-distance variable (*DISTWELL99*, *DISTWELL08*, and *DISTWELL09*) with an associated post-disclosure dummy variable: *POST99*, *POST08,* and *POST09*.

DATA DESCRIPTION

The sample includes 186 qualified vacant land parcels in Buncombe County, NC which sold between 1996 and 2012, all of which are less than two kilometers (1.24 miles) from the contamination site. All parcel transaction data were obtained from the Buncombe

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[17] We initially distinguished between these flows as well. After initial estimation, we could not reject the null hypothesis that the two shallow variables had the same impact on parcel prices nor could we reject then null hypothesis that the two deep variables had the same impact on parcel prices. We therefore constrain the two shallow parameters to be the same as well as the two deep parameters to be the same. Our final specification, as displayed in equation (1), includes only one SHALLOW and one DEEP dummy variable, and post-1999 interactions for both.

County, NC Tax Department and the geographic placement data were obtained via ArcGIS.

A map of the study area is provided in Figure 1. The study area is located in the south of Buncombe County in the lower left corner of the figure. The contamination site is denoted in the center of the larger sales map. Because the site is located in a saddle between two watersheds, it affects two distinct streams which flow in opposite direction from the site (to the northwest and southeast, respectively.) Properties downstream from the site are located along the lighter shaded corridor that generally follows the path of these two streams. The shaded triangles extending outward from the site show the predicted directions of groundwater flows based on the EPA studies of sampled bedrock crack orientations.

Table 1 lists the variables used in the analysis and their descriptions. Table 2 reports the descriptive statistics of the data. The average transaction price was $182,486 and the average parcel size was 1.36 acres. The average slope of the parcels was 10.78, consistent with the mountainous terrain of the area, and the average parcel was located 735 feet above sea level. The average parcel was 11.45 miles away from the central business district of Asheville and thirty-four percent of the parcels were located within the city limits of Asheville. Thirteen percent of parcels were associated with a surface stream and eleven percent of the sample is associated with a stream and also sold after the contamination was made public. Eleven percent of parcels were located on a stream and also considered downstream from the contamination site and nine percent of the sample was downstream from the site and sold after the contamination was made public. Fifteen percent of parcels are located either to the northwest or south-by-southeast of the site and lie in the path of estimated shallow groundwater contamination plumes. Seventeen percent of the parcels are located either to the southwest or north-by-northeast of the site, and lie in path of estimated deep groundwater plumes. The average parcel was 1.37 miles away from the well that was found to be contaminated in 1999, 1.68 miles from the well found to be contaminated in 2008, and 1.58 miles from the well found to be contaminated in 2009. Among those parcels that sold after the contamination of each of the three wells was made public, the average parcel was 0.87 miles from the 1999 well, 1.11 miles from the 2008 well, and 1.03 miles from the 2009 well.

ESTIMATION RESULTS

Table 3 reports the estimation results. Six models are reported. Model (1) includes only parcel characteristics; model (2) includes parcel and surface water characteristics; model (3) includes parcel and ground water characteristics; model (4) includes parcel, surface, and ground water characteristics; model (5) includes parcel and well characteristics; and model (6) includes parcel, ground water, and well characteristics. All models include year fixed effects (not reported for brevity) and exhibit non-specific heteroscedasticity; thus White (1980) robust standard errors are used for inference.

In all models, the lot-size elasticity of price is positive and statistically different from zero and statistically less than one, consistent with other studies. On average, a one percent increase in lot size corresponds with an increase in sale price of approximately 0.75 percent. In all models the slope of the parcel is negatively related to transaction price, consistent with Chamblee, et al. (2009 and 2011), which reflects increased development costs and lower amenity value of steep parcels. On average, a one unit increase in slope corresponds with a decrease in transaction price of approximately two percent. Elevation, on the other hand, is not a significant contribution to transaction price. The distance from the Asheville central business district is positively related to price in Model (1) and Model (2) but for the other models distance is not statistically meaningfully. A City of Asheville location increases price by a factor of 3.5, reflecting the increased amenities and services that being within the city of Asheville provides.

The distance of a parcel from the contamination site is negative in Model (1) and Model (2) suggesting that the contamination site might be in a value peak. However, we note that the significance of this variable disappears as we start to control for hydrological variables suggesting that the statistically significant result is perhaps the result of an omitted variables bias. We find no significant price effects related to distance from the site after the discovery of off-site contamination.

Looking at Model (2), which includes the variables *STREAM* and *DOWNSTREAM*, we find no price effects to properties that are associated with a stream. However, properties that are downstream from the contamination site carried a price premium of approximately 97 percent before the contamination was made public. After the off-site contamination became public, properties downstream from the site lost their entire premium so that they sold for no more than non-downstream properties.[18]

In Model (3) the groundwater characteristics are substituted for surface water characteristics and in Model (4), discussed further below, both groundwater and surface water characteristics are included. In Model (3) properties that are in the path of potentially contaminated shallow ground water located to the northwest and the south--

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[18] The sum of the parameters on *DOWNSTREAM* and *DOWNSTREAMPOST* is -0.239, p=0.281.

southeast of the site experienced price premiums of 242 percent over other similar properties before the off-site contamination was made public. Yet, after the off-site contamination was made public the entire premium was erased.[19] In Model (3) properties that sit in the path of potentially contaminated deep groundwater to the southwest and the north-northeast of the contamination site did not experience a price premium in the pre-announcement period. In the post-announcement period there is no deleterious impact on property prices as reflected by the insignificant parameter on *DEEPPOST*.

In Model (4), both surface water and ground water characteristics are included. In this case all surface water characteristics are rendered insignificant and the only characteristics that have a statistically meaningful relationship with parcel prices are those associated with shallow groundwater. As before, those properties that sit in the path of potentially contaminated shallow groundwater carried a price premium before the contamination was made public. After the discovery of offsite contamination, those properties that fall in the shallow groundwater contamination plume had their price premium erased.[20]

In Model (5), all surface and groundwater characteristics are substituted by the distances to the three private wells that were discovered contaminated at various times during the sample period. All of the parameters associated with the six well-related variables are statistically insignificant suggesting that proximity to a contaminated well did not alter the market valuation of a property before and after their contamination was made public.

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[19] The sum of the parameters on *SHALLOW* and *SHALLOWPOST* is -0.193, p=0.294.

[20] The sum of the parameters on *SHALLOW* and *SHALLOWPOST* is -0.078, p=0.661.

In Model (6), groundwater characteristics and well characteristics are included (with surface water characteristics excluded). This model thus includes those characteristics that focus on the potential contamination of water under the surface of the properties, both shallow and deep. In this case, five of the six well variables remain insignificant but there appears to be a premium paid for distance from the 2008 well after the contamination was discovered. As before, those properties in line of potentially contaminated shallow ground water carry a premium before the discovery of off-site contamination and suffer a price reduction after the contamination was made public.[21]

Economically, the results suggest four interesting aspects of this market with respect to potential contamination. First, property owners are not terribly concerned about surface water that might be contaminated. This is perhaps reasonable given the low residence time for potential surface contamination. Second, there are price discounts for parcels that could experience contaminated shallow groundwater. This might reflect a perception that potentially contaminated shallow ground water might carry a higher probability to contaminate a parcel's soil thereby increasing risk to flora and fauna on the property. Third, the market does not seem capitalize the potential for deep groundwater contamination even though the deep groundwater might have more long-term health impacts than other types of contamination. Fourth, the market does not seem to respond to every announcement of off-site contamination, as reflected in only one of the post-

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[21] To confirm that the estimation results in Table 3 are not the result of specification error, we undertook a number of different robustness tests, the tabular results of which are available from the authors upon request. One test was to calculate the path distance from the contamination site to the parcel along a stream; there was no impact pre- or post-announcement. We also considered whether the parcel buyer was a so-called "outsider" or not from one of the eleven zip codes in Asheville and the immediate vicinity; our intuition is that perhaps buyers from outside the area would have less information about the contamination than locals. In no specification was the outsider effect a significant contributor to parcel prices either on its own or interacted with surface and groundwater characteristics. In all cases, the deep and shallow groundwater results remain essentially unchanged and inferences do not change.

disclosure well-related variables being statistically significant and suggesting that distance from that particular well carried a premium. Econometrically the results suggest that failing to control for potential groundwater contamination, both shallow and deep, in this particular market might introduce significant omitted variables bias.

CONCLUSION

In this study we examine the effects of off-site water contamination from a former manufacturing site in Buncombe County, NC. The contamination site was designated an Environmental Protection Agency (EPA) Superfund site in March 2012. Between 1952 and 1986, the owners of the site engaged in electroplating as part of their manufacturing process and used the main water contaminant, the chlorinated solvent trichloroethylene (TCE), which is associated with various adverse health consequences, including cardiac problems, liver injury, and neurological problems.

We examine how perceived risk of water contamination is capitalized into nearby property values. We use a hedonic model where the land prices are regressed on a composite of key characteristics, including hydrological site characteristics and distance of parcels from the contaminated site. The different models allow us to test how land market participants understand the spatial aspects of water contamination. We find that when not controlling for groundwater contamination, it appears that potential surface water contamination has a statistically significant and economically material impact on property values. However, when including variables describing potential groundwater contamination, the surface water effects disappear. In this market, parcels that face potential shallow groundwater contamination suffered substantial price declines after off-site contamination was found. However, potential deep groundwater contamination, which might pose greater long-term health risks, is not generally incorporated into transaction prices. Our findings suggest that studies of house price effects from water contamination should consider hydrologic variables, including both surface water and groundwater flow estimates, in cases where the terrain is varied.

The current study suggests that land market participants have incomplete information with regard to contamination. Surface water and shallow groundwater flows may be roughly "guesstimated" using a basic knowledge of an area's terrain and understanding of water flows above ground. By contrast the flow of water through bedrock may have little to do with the shape of the surface topography, as was the case with the deeper groundwater flows in this instance. In all cases, groundwater contamination predictions are dependent not only upon rock composition and the chemical composition of the contaminants themselves, but also on subsurface crack orientation which is usually not related to terrain, but rather the result of the geologic processes of folding, faulting and uplift that could have happened hundreds of thousands or millions of years ago.

The estimated loss in property value from the risk of shallow groundwater contamination is substantial. Evaluated at the sample mean, our results suggest that land prices decline by between $126,580 and $139,680 following the public's awareness off-site contamination. However, these price effects are consistent with Abdalla, et al. (1992) who examine Perkasie, PA household expenditures in response to TCE groundwater contamination. Estimates of expenditures associated with bottled water purchases, home treatment systems, and the hauling and boiling of water between December 1987 and

September 1989 ranged from $61,313 to $131,334. Adjusting for inflation, this range becomes $111,620 to $239,091 in 2012 dollars; the estimated shallow groundwater price effects from Models 3, 4, and 6 all fall in this range.

In general our analysis may underestimate the cost of contamination of properties subject to contamination or contamination risk if some of these parcels are no longer marketable. Realtors operating in this market must reveal the nature of the contamination and the regulatory status of the site to potential buyers. Indeed the site has become somewhat notorious on a national scale. The Department of Justice submitted a brief in support of the site owner's position. The site owner is also challenging in appellate court the EPA's decision to place their site on the NPL in 2012, specifically challenging the linkage between contamination and their property.[22] It remains to be seen whether the owner, as the potentially responsible party, has the legal standing to challenge this decision.[23]

The U.S. Supreme Court will soon rule as to whether local citizens (under nuisance) can sue the site owner for damages, which they can if the high court rules that CERCLA preempts North Carolina's 10 year statute of repose.[24] Unlike a statute of limitations, which places limits on how long after damages one can bring a claim against a polluter, a statute of repose places a limit on how long after pollution was released one can bring a claim against a polluter. A statute of repose is important in this context because of the slow rate of groundwater movement and the complexity of the underlying geology it may take years or even decades to adequately understand the impact of a pollutant's release on even nearby groundwater sources.

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[22] Superfund Report 17 February 2014.
[23] Superfund Report 14 April 2014.
[24] No. 13-339 In the Supreme Court of the United States: CTS Corporation v. Peter Waldburger, et al.

REFERENCES

Abdalla, C. W., B. A. Roach and D. J. Epp. 1992. “Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination.” *Land Economics* 68 163-69.

Boyle, M. A. and K. A. Kiel. 2001. “A Survey of House Price Hedonic Studies of the Impact of Environmental Externalities.” *Journal of Real Estate Literature* 9 117-44.

Chamblee, J.F., P.F. Colwell, C. A. Dehring and C.A. Depken. 2011. “The Effect of Conservation Activity on Surrounding Land Prices.” *Land Economics* 87 453-72.

Chapman, Melinda J. and Brad A. Huffman. 2011. Geophysical Logging Data from the Mills Gap Road area near Asheville, North Carolina. Data Series 538. U.S. Department of the Interior, U.S. Geological Survey. Accessed 24 January 2014. (http://pubs.usgs.gov/ds/538/pdf/ds538.pdf)

Colwell, P. F. and C.F. Sirmans. 1993. “A Comment on Zoning, Returns to Scale, and the Value of Undeveloped Land.” *The Review of Economics and Statistics* 75 783-86.

CTS Corporation v. Peter Waldburger, et al. No. 13-339. In the Supreme Court of the United States.

Dale, L., J. C. Murdoch, M. A. Thayer and P. A. Waddell. 1999. “Do Property Values Rebound from Environmental Stigmas? Evidence from Dallas.” *Land Economics* 75 311-326.

Epp, D. J. and K. S. Al-Ani. 1979. “The Effect of Water Quality on Rural Nonfarm Residential Property Values.” *American Journal of Agricultural Economics* 61 529–34.

Fetter, C.W. 2001. *Applied Hydrogeology.* 4th edition. Prentice-Hall. Upper Saddle River, New Jersey.

Gayer, T., T. Hamilton, and W. Viscusi. 2002. "Private Values of Risk Tradeoffs at SuperfundSites: Housing Market Evidence on Learning about Risk." *Review of Economics and Statistics* 82 439-51.

Greenstone, M. and J. Gallagher. 2008. “Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program. “ *Quarterly Journal of Economics* 123 951-1003.

Kiel, K.A. 1995. “Measuring the Impact of the Discovery and Cleaning of Identified Hazardous Waste Sites on House Values.” *Land Economics* 74 428-35.

Kiel, K.A. and K.T. McClain. 1995. “House Prices During Siting Decision Stages: The Case of an Incinerator From Rumor Through Operation.” *The Journal of Environmental Economics and Management* 28 241-55.

Kiel, K. A. and M. Williams. 2007. “The Impact of Superfund Sites on Local Property Values: Are All Sites the Same?” *Journal of Urban Economics* 61 170-92.

Kiel, K. A. J. Zabel. 2001. Estimating the Economic Benefits of Cleaning Up Superfund Sites: The Case of Woburn, Massachusetts.” *Journal of Real Estate Finance and Economics* 22 163-84.

Kohlhase, J.E. 1991. “The Impact of Toxic Waste Sites on Housing Values.” *Journal of Urban Economics* 30 1-26.

Michaels, R. G. and V. K. Smith. 1990. “Market Segmentation and Valuing Amenities with Hedonic Models: The Case of Hazardous Waste Sites.” *Journal of Urban Economics* 28 223-42.

McLaughlin, P. A. 2011. “Something in the Water? Testing for Groundwater Quality Information in the Housing Market.” *Journal of Agricultural and Resource Economics* 36 375–94.

McMillen, D. P. and P.Thorsnes. 2000. “The Reaction of Housing Prices to Information on Superfund Sites: A Semiparametric Analysis of the Tacoma, Washington Market.” *Advances in Econometrics* 14 201-28.

Mendelsohn, R. 1992. “Measuring Hazardous Waste Damages with Panel Models.” *Journal of Environmental Economics and Management* 22 259-71.

Michael, H. J., K. J. Boyle, and R. Bouchard. 1996. “Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes.” No. 398 in Miscellaneous Report. Orono, ME: University of Maine, Maine Agricultural and Forest Experiment Station.

http://mountainx.com/news/040908ctssite/

Paunovic, Milan and Mordechay Schlesinger. 2006. *Fundamentals of Electrochemical Deposition.* 2nd Edition. John Wiley & Sons, Inc. Hoboken, New Jersey.

Plummer, L.N., E. Busenberg, J.K. Böhlke, D.L. Nelms, R.L. Michel, P. Schlosser. 2001. “Groundwater Residence Times in Shenandoah National Park, Blue Ridge Mountains, Virginia, USA: a multi-tracer approach. *Chemical Geology* 179(2001):93-111.

Rosen, S. 1974. “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.” *Journal of Political Economy* 82 34-55.

Steinnes, D. N. 1992. “Measuring the Economic Value of Water Quality.” *Annals of Regional Science* 26 171–76.

Superfund Report. 17 February 2014 *SUFR* 28 (4).

Superfund Report. 14 April 2014 *SUFR* 28 (8).

Tague, C.L., L.E. Band. 2004. “RHESSys: Regional Hydro-Ecologic Simulation System—An Object-Oriented Approach to Spatially Distributed Modeling of Carbon, Water, and Nutrient Cycling.” *Earth Interactions* 2004 8:1-42.

U.S. Environmental Protection Agency. HRS Documentation Record for CTS of Asheville, Incorporated. Prepared March 2011, Revised March 2012.
U.S. Geological Survey. 2014. “What is Groundwater?” U.S. Geological Survey Open File Report 93-643. Accessed 24 January 2013. (http://pubs.usgs.gov/of/1993/ofr93-643/).

White, Hal (1980) XXX

Wischkaemper, Kay. 2011. Technical Memorandum on the Geology and Hydrogeology in the Mills Gap Road Area of Buncombe, County North Carolina. Redacted Memorandum of the Environmental Protection Agency. Accessed January 24, 2014. (http://www.epa.gov/region4/superfund/images/nplmedia/pdfs/millsgapnchydmemo.pdf)

FIGURE 1
MAP OF SALES AND STUDY AREA

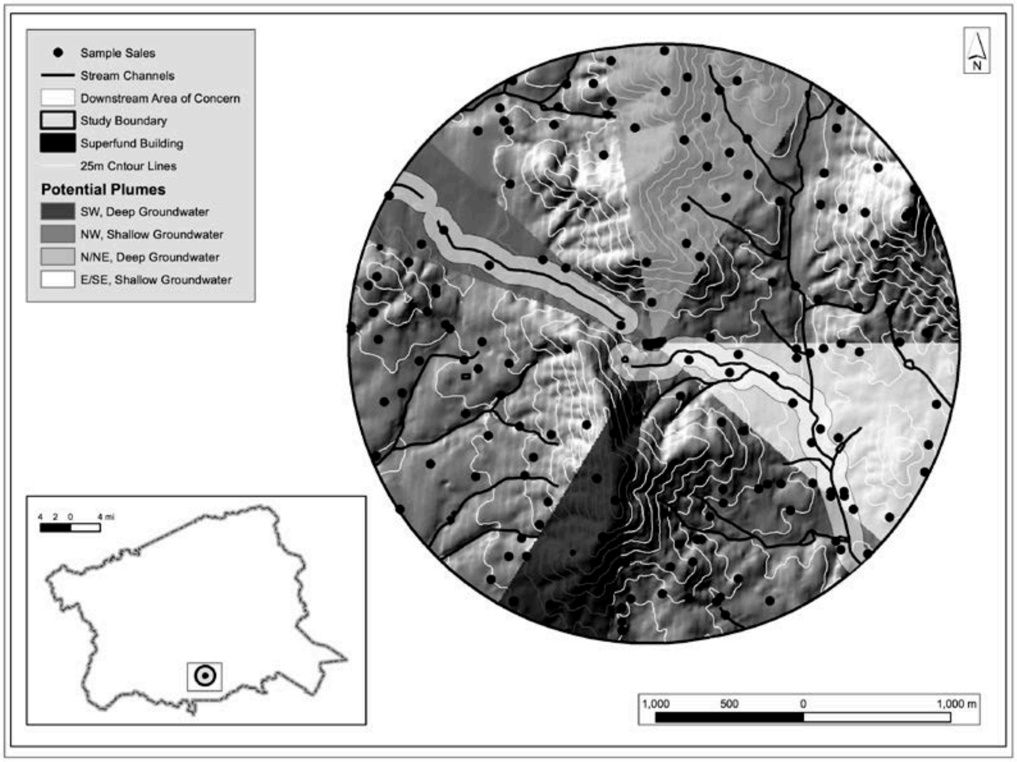

Table 1: Variable Descriptions

	Variable	Description
Parcel Characteristics	*PRICE*	Transaction price
	ACRES	Parcel size in acres
	SLOPE	Slope of parcel
	ELEV	Elevation of parcel
	DISTHISTCBD	Euclidean distance to Asheville Historical Central Business District
	CITYASH	Parcel is within the city of Asheville
	DIST	Distance from parcel centroid to contamination site
	DISTPOST	*DIST* x Sale after 1999
Surface Water Characteristics	*STREAM*	Parcel borders or contains a stream
	STREAMPOST	*STREAM* x Sale after 1999
	DOWNSTREAM	Parcel is downstream from contamination site
	DOWNSTREAMPOST	*DOWNSTREAM* x Sale after 1999
Ground Water Characteristics	*SHALLOW*	Parcel has shallow ground water Northwest or South-Southeast of site
	SHALLOWPOST	*SHALLOW* x Sale after 1999
	DEEP	Parcel has deep ground water Southwest or North-Northeast of site
	DEEPPOST	*DEEP* x Sale after 1999
Off-site Well Contamination	*DISTWELL99*	Euclidean distance to well found contaminated in 1999
	DISTWELL08	Euclidean distance to well found contaminated in 2008
	DISTWELL09	Euclidean distance to well found contaminated in 2009
	DISTWELL99POST	*DISTWELL99* x Sale after 1999
	DISTWELL08POST	*DISTWELL08* x Sale after 2008
	DISTWELL09POST	*DISTWELL09* x Sale after 2009

Table 2: Descriptive Statistics of the Sample

	Mean	Std. Dev.	Min	Max
PRICE	182,486	358,230	1,000	3,600,000
ACRES	1.36	1.60	0.08	8.84
SLOPE	10.78	6.98	0.02	40.67
ELEVATION	735.43	49.71	672.86	925.59
DISTHISTCBD	11.45	1.10	9.30	13.21
CITYASH	0.34	0.48	0.00	1.00
DIST	1.40	0.44	0.18	1.99
DISTPOST	0.89	0.75	0.00	1.99
STREAM	0.13	0.34	0.00	1.00
STREAMPOST	0.10	0.30	0.00	1.00
DOWNSTREAM	0.11	0.32	0.00	1.00
DOWNSTREAMPOST	0.09	0.29	0.00	1.00
SHALLOW	0.15	0.35	0.00	1.00
SHALLOWPOST	0.13	0.33	0.00	1.00
DEEP	0.16	0.37	0.00	1.00
DEEPPOST	0.07	0.26	0.00	1.00
DISTWELL99	1.57	0.61	0.22	2.78
DISTWELL08	1.68	0.73	0.10	3.06
DISTWELL09	1.36	0.49	0.10	2.21
DISTWELL99POST	1.03	0.90	0.00	2.67
DISTWELL08POST	0.04	0.31	0.00	2.76
DISTWELL09POST	0.03	0.23	0.00	1.88

Table 3: Estimation Results

VARIABLES	(1) lnprice	(2) lnprice	(3) lnprice	(4) lnprice	(5) lnprice	(6) lnprice
LNACRES	0.740***	0.741***	0.725***	0.723***	0.743***	0.740***
	(0.076)	(0.076)	(0.078)	(0.078)	(0.076)	(0.077)
SLOPE	-0.023**	-0.025***	-0.023***	-0.024***	-0.027***	-0.028***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)
ELEVATION	0.001	0.001	0.001	0.001	0.002	0.003*
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
DISTHISTCBD	0.155***	0.146**	0.148**	0.140**	-0.113	-0.101
	(0.059)	(0.062)	(0.058)	(0.061)	(0.152)	(0.167)
CITYASHE	1.498***	1.490***	1.430***	1.436***	1.425***	1.374***
	(0.148)	(0.151)	(0.140)	(0.140)	(0.160)	(0.152)
DIST	-0.482*	-0.481*	-0.305	-0.316	0.869	0.962
	(0.277)	(0.277)	(0.290)	(0.306)	(0.753)	(0.913)
DISTPOST	0.211	0.158	0.006	-0.014	0.209	0.137
	(0.312)	(0.306)	(0.324)	(0.337)	(0.363)	(0.368)
STREAM		-0.020		0.053		
		(0.469)		(0.371)		
STREAMPOST		0.327		0.228		
		(0.488)		(0.397)		
DOWNSTREAM		0.676*		0.177		
		(0.390)		(0.406)		
DOWNSTREAMPOST		-1.028**		-0.481		
		(0.439)		(0.456)		
SHALLOW			1.203***	1.105**		1.065**
			(0.379)	(0.447)		(0.409)
SHALLOWPOST			-1.396***	-1.183**		-1.450***
			(0.417)	(0.480)		(0.439)
DEEP			-0.029	-0.033		-0.001
			(0.300)	(0.312)		(0.323)
DEEPPOST			-0.201	-0.179		-0.343
			(0.363)	(0.377)		(0.353)
DISTWELL99					-0.604	-1.094
					(1.517)	(1.610)
DISTWELL99POST					-0.022	-0.182
					(0.267)	(0.263)
DISTWELL08					0.891	1.234
					(0.999)	(1.045)
DISTWELL08POST					1.158***	1.410***
					(0.321)	(0.362)
DISTWELL09					-1.447	-1.205
					(0.958)	(1.274)
DISTWELL09POST					0.293	0.114
					(0.499)	(0.622)
Constant	9.100***	8.976***	8.384***	8.403***	10.401***	9.331***
	(1.290)	(1.266)	(1.311)	(1.367)	(1.726)	(2.071)
Observations	186	186	186	186	186	186
R-squared	0.635	0.647	0.655	0.660	0.654	0.676

Notes: All specifications include year fixed effects. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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