Meta-Functional Transfer of Hedonic Property Values: Application to Great Lakes Areas of Concern

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This paper explores the use of functional benefits transfer to forecast the effects of waste sites on property values. The results of a meta-analysis of hedonic studies of waste sites are coupled with spatial analysis techniques to produce estimates of the effects of toxic contamination in Areas of Concern (AOCs) in the U.S. Great Lakes. Based on U.S. Census data for median home values, the methods used here suggest that approximately $5.2 billion (2005 dollars) have been lost in residential property values surrounding twenty-three of the AOCs. This compares to estimates that place the cost of remediation of all U.S. AOCs at up to $4.5 billion (2005 dollars). The case study also identifies issues surrounding the use of a meta-analysis with hedonic property value studies to support functional transfer.

Key Words: benefits transfer, meta-analysis, hedonic method, property values, Great Lakes, Areas of Concern

This paper contributes in a new and different way to the literature on the economic impacts of contaminated sites. We develop a method to forecast the effects of toxic wastes on nearby property values at sites where those impacts have not been studied in detail. The goal is a methodology for determining the sites that have exacted the greatest external costs.

Our method draws on the methodology developed for benefits transfer. Benefits transfer is the application of relationships derived from original research to predict outcomes in data contexts related to but not included among the background studies (Rosenberger and Loomis 2003). We use a functional transfer approach where the value function is based on the results of a meta-analysis. This exercise offers insights into the potential for and limitations of functional transfer techniques based on hedonic property value studies.

Our investigation addresses an important and visible class of contaminated sites—the forty-three sites around the U.S. Great Lakes officially recognized by the International Joint Commission (2003) as Areas of Concern (AOCs). AOCs are extremely impaired river or coastal areas in the Great Lakes Basin; most AOCs are associated with terrestrial sites included on the National Priority List (NPL) for cleanup under the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund, 42 U.S.C. 103). At these sites, hazardous wastes from

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former industrial sites are found. Contaminants from those sites have been discharged or have migrated into river and lake sediments, at which point they are no longer confined to private property but are resident in an internationally governed public resource. Thus, in addition to Superfund, the cleanup of offshore contamination has been justified in part by international commitments under the Great Lakes Water Quality Agreement (International Joint Commission 1978) and supported by more than $126 million in federal expenditures under the Great Lakes Legacy Act of 2002 (P.L. 107-303), reauthorized in 2008 (P.L. 110-365). The federal expenditures have leveraged more than $68 million in additional nonfederal matching funds (U.S. EPA 2009). As a result of these expenditures, 1.7 million pounds of contaminants have been removed from U.S. AOCs since 2002.

This study provides the first effort to estimate either the relative economic importance or the cumulative effects for this policy-relevant class of sites. Specifically, we use a meta-functional benefits transfer methodology to attempt to estimate the losses in property values that were associated with contamination of the AOCs. The methodological goal of the study is to discern the strengths and weaknesses of this transfer methodology for use in forecasting the economic impact of environmental hazards; the Great Lakes AOCs provide an opportunity to examine this methodology in practice. The policy goal is to learn how the expenditures on remediation compare to the magnitude of the losses from contamination. The latter quest is distinct from whether those expenditures will restore the losses in property values. As McCluskey and Rausser (2003) and Kiel and Williams (2007) observe, remediation of a contaminated site may not reverse the previous losses. Community dynamics, operating alongside the changes in environmental conditions, may alter the relationship between environmental conditions and property markets.

Hedonic Property Value Studies of Contaminated Sites

Industrial contamination of real estate is a massive problem in the United States. By the mid-1990s, more than $11 billion in public funds and another $11 billion in private funds had been spent on the cleanup of legacy toxic wastes (U.S. EPA 1996). A decade later, federal expenditures on the cleanup of sites qualifying under Superfund had grown to $35 billion, averaging $43 million per site (2005 dollars) (Greenstone and Gallagher 2008). Nevertheless, hundreds of sites remain on the Superfund NPL, and thousands more have been recommended for remediation but are not considered sufficiently hazardous to be eligible for federal funds.

Legacy industrial contamination is believed by many cities to hamstring their opportunities for economic transformation and development. The potential for external impacts of these sites on the usefulness and value of neighboring properties elevates the issue from a private to a public concern. For property owners and local officials, the possibility of recovering lost property values, both on- and off-site, is an important motivation for cleanup. Given the large number and daunting costs of cleaning the remaining sites, the pressure is great to ensure a positive return on investment.

The external impact of toxic contamination has been a topic of extensive study in the environmental economics literature (e.g., Faber 1998, Simons 2006, Kiel and Williams 2007, Greenstone and Gallagher 2008). This literature is dominated by hedonic property value studies. After controlling for structural, public services, amenities, transportation, and other influences on those values, these studies estimate differences between property values near to and far from contaminated sites. Under specific assumptions about the property market (Taylor 2003), the hedonic value attributed to proximity to the contaminated site measures the capitalized market value of the contamination (or cleanup). While hedonic property value studies of waste sites number only in multiples of ten, there are thousands of sites where evidence of economic impact would be helpful to decision makers. The typical detailed study requires specialized expertise and may cost hundreds of thousands of dollars, so the question arises: What can we learn from the existing studies that might reasonably be extrapolated to other sites at low cost?

The literature includes several attempts to answer to this question. Faber (1998), Kiel and

Boyle (2001), and Simons (2006) provided qualitative reviews of the literature but did not derive specific guidance for extrapolation. Simons and Saginor (2006) embedded contaminated sites in a quantitative meta-analysis of studies that examined wide-ranging influences, from sex offenders to livestock odors, on real estate values. Braden, Feng, and Won (2009) provided a quantitative meta-analysis focusing more specifically on waste sites. We will return to the findings of the latter study below.

Several studies have attempted to quantify the economic effects of cleanup, as distinct from the effects of contamination. Most of them are case studies of individual sites (e.g., Kiel 1995, Dale et al. 1999, McCluskey and Rausser 2003), but two of them consider multiple sites. Kiel and Williams (2007) estimated hedonic property value functions for fifty-seven sites on the National Priority List. Only eighteen of the sites revealed positive and significant effects for the distance variable. Kiel and Williams then regressed a dummy variable for the sign and significance of the distance coefficient (0 = negative or insignificant) on descriptive variables about the sites and found that the size of the contaminated site, the size of the property sales sample, and the "blue-collar" composition of the neighborhood were associated with significant effects. They concluded that the effects of NPL sites and their remediation are highly variable and not amenable to generalization. Finally, using census tract data, Greenstone and Gallagher (2008) applied a difference-in-differences methodology to compare housing price appreciation rates (rather than levels) around NPL sites where cleanup had and had not occurred. They found that cleanup was not associated with a statistically significant difference in the evolution of nearby property values or the composition of the resident population.

Functional Benefits Transfer with Hedonic Property Values

Following Rosenberger and Loomis (2003), the goal of benefits transfer is to derive estimates of policy site values V_{Pj} for policy sites $j = 1, \ldots, J$ from the summary statistics V_{Si} of original research conducted at study sites $i = 1, \ldots, I$. P is the vector of policy sites, and S is the vector of study sites. The study site values (V_S) are transformed through a function $Ø_S$, which is based on the study site values, to produce a transfer value at a policy site j (V_{Pj}) where P is a vector of policy sites:

$$Ø_S(V_S) => V_{Pj}\,. \quad (1)$$

In most transfer studies, the transformation function $Ø_S$ reduces to a single multiplier drawn from previous research—for example, a median value of a statistical life or a representative value of a fish or bird harvested. The multiplier is generally based on estimates of marginal value or elasticity applied without adjustment for contextual circumstances. This approach is illustrated by Faber (1998). In reviewing the economic literature on waste sites, he derived an average value per mile of distance from a contaminated site. The average differed only by the type of site (hazardous, sanitary, chemical, or nuclear), not by the character of the surrounding area.

Functional benefits transfer offers a more nuanced approach. It attempts to capture contextual factors in a multivariate transformation function. Once again adapting Rosenberger and Loomis (2003), we define a meta-analysis transfer function for policy site j as:

$$V_{Pj} = Ø_S(Q_{s|j}, X_{s|j}, M_{S|j})\,. \quad (2)$$

Equation (2) states that the benefit transfer function $Ø_S$ is estimated based on the vector S of study sites and calibrated to policy site j. Both the original estimation and the ensuing calibration use observations on three classes of variables: (a) site quantity/quality variables (Q_S); (b) site and data characteristics (X_S); and (c) methodological variables (M_S). For example, the Q vector might include the types and amounts of contaminates; the X vector might specify the number of homes impacted and the date(s) when data were collected; and the M vector might reflect whether an estimated relationship was linear or nonlinear and considered a spatial correlation. The M vector is a unique feature of the meta-functional formulation. It provides for the possibility that various methods may have been used to generate the study site observations, and that the methods used may account in part for the values produced.

Thus, in transferring estimates, the analyst may need to select a preferred valuation methodology. Once estimated, the transfer function is calibrated to a policy site *j* using the *Q* and *X* values for that site plus appropriate values of *M*. Functional transfer of this kind is thought to generate more accurate estimates than simple value transfer methods because it takes systematic account of the characteristics of the policy site rather than applying an "average" value irrespective of local conditions (Rosenberger and Loomis 2003).

Meta-analysis (Stanley 2001) is one means of deriving a multivariate transfer relationship. A meta-analysis collects a class of original studies of a particular relationship and attempts to explain variation in their conclusions based on differences between the studies. To the extent that the differences are due to particular facts surrounding the various studies—either facts on the ground or facts about the studies themselves—the meta-analysis elucidates how they affect the results through the vector *M* in expression (2).

The first step in a meta-analysis functional transfer is to conduct a meta-analysis of study sites. To date, hedonic methods have been used in six studies of five Great Lakes AOCs (Braden et al. 2004, Braden et al. 2008a and 2008b, Chattopadhyay, Braden, and Patunru 2005, McMillen 2006, Zegarac and Muir 1998). The small number of studies of AOCs precludes robust statistical estimation of a meta-function for those sites alone. We begin instead with the meta-analysis of wastes sites by Braden, Feng, and Won (2009). The waste sites considered in that study include nonhazardous landfills, hazardous waste sites on land, and nuclear facilities, as well as underwater hazardous waste sites. Their analysis is based on 142 observations drawn from 46 studies of such sites. Included among the sites analyzed in these studies are five AOCs and one non-AOC underwater site. (More than fifty additional terrestrial hazardous waste sites were analyzed by Kiel and Williams (2007). These observations would have substantially enriched the meta-analysis of Braden, Feng, and Won (2009). However, Kiel and Williams' published study provided insufficient detail on individual sites for inclusion in the meta-function estimation.)

Braden, Feng, and Won (2009) convert the value impacts from absolute to percentage (of property value) terms. As a result of this normalization, inflation should not be an issue for studies that occurred at different times, and regional differences in real estate market conditions should be neutralized. For the entire sample of studies, the mean property value reduction is approximately 6 percent. The areas over which impacts are estimated average 6.7 radial miles in size. A variety of statistical tests were applied to identify outliers. Thirteen such observations were identified; so the final sample used for meta-function estimation contained 129 observations, with an average mean distance of three miles from the noxious site and an average proportional impact on property values of 4.5 percent.

Table 1 lists and defines the explanatory variables in the meta-function. The estimated function is simply a linear expression in these variables. Several estimators were tested, including robust ordinary least squares (OLS), a random effects panel estimator, and weighted least squares. The estimators were applied to various model specifications. The signs and significance of the explanatory variables were remarkably robust across specifications. The preferred model used weighted least squares applied to a relatively parsimonious specification. This is the model summarized in Table 1. Among the models tested, it had the highest adjusted-R^2 value, and produced relatively conservative estimates of overall impact. The coefficient estimates from the preferred specification appear in the "Coefficient" column of Table 1, together with the significance levels of the estimates.

The results of Braden, Feng, and Won (2009) indicate that the economic impacts of waste sites are concentrated in the vicinity of the contamination. Prices within one mile of the site can be discounted by more than 10 percent, but the discount diminishes with distance. There were no statistically significant differences in the percentage impacts estimated by linear versus nonlinear specifications of the distance variable. However, most of the underlying studies conclude that nonlinear functions are more consistent with economic theory and best fit the data.

Table 1. Illustrative Application of Transfer Methodology to the Ashtabula River, OH AOC

Independent Variable	Coefficient [a]	Sig.[b]	No. Non-zero Observ.	Transfer Calibration	Policy Site PPE Estimate (%)
Constant	-42.949	***	n/a	1	-42.949
Nonhaz (0,1=Non-hazardous site)	Default		29	0	0
Terr (0,1=Terrestrial site)	14.049	***	76	0	0
Aquatic (0,1=Aquatic site)	21.219	***	14	1	21.219
Nuclear (0,1=Nuclear site)	2.230		10	0	0
MSite (0,1=Multiple waste sites included in study)	-3.127	*	51	1	-3.127
Pacific (0,1=Pacific Region)	6.386		3	0	-6.386
Mountain (0,1=Mountain Region)	12.495	**	3	0	-12.495
WNCent (0,1=West Northcentral Region)	-6.327	*	6	0	6.327
ENCent (0,1=East Northcentral Region)	Default		33	1	58.561
MidAtl (0,1=Mid-Atlantic Region)	9.837	***	17	0	-9.837
NewEng (0,1=New England Region)	1.268		34	0	-1.268
WSCent (0,1=West Southcentral Region)	-2.272		13	0	2.272
ESCent (0,1=East Southcentral Region)	11.514	***	3	0	-11.514
SAtlant (0,1=South Atlantic Region)	8.831	***	18	0	-8.831
Canada (0,1=Canada)	16.828	***	7	0	-16.828
NPL (0,1=On NPL)	-5.452	**	27	1	-5.452
Residen (0,1=Data are for residential property)	16.141	***	114	1	16.141
MeanDt (Mean distance from property to the site)	-0.916	***	n/a	1.41	-1.292
Sample (Sample size)	-3.110E-05		n/a	4,582	-0.143
IndSale (0,1=Data are for individual property sales)	12.815	***	115	0.891	11.419
Demoecon (0,1=Demographic & economic data included)	-6.259	***	63	0.488	-3.057
Access (0,1=Other accessibility data included)	6.305	***	73	0.566	3.568
Publish (0,1=Published)	9.820	***	117	0.907	8.906
Linear (0,1=Linear model)	-1.091		28	0.217	-0.237
Sig (0,1=Estimate of environmental coeff. is significant)	3.585	**	91	0.705	2.529
Sar (0,1=Spatial autocorrelation controlled)	3.723		9	0.070	0.260
N = 129, K = 24, Adj. R^2 = 0.568					
Estimated PPE (%) for a single house in policy site					7.785 [c]
Median price impact ($2000) per owner-occupied residence					$6,557
Total median price impact ($2000), tracts within 2-mile zone					$63,914,493

[a] Coefficient estimates and significance from Braden, Feng, and Won (2009).
[b] * Sig. at 10% level, ** Sig. at 5% level, *** Sig. at 1% level.
[c] Estimate equals the sum of the coefficients for non-default variables of this category times the respective transfer calibration values.

According to Braden, Feng, and Won (2009), studies of aquatic sites produce estimates of economic impacts that are approximately 11 percentage points greater than the full sample average value reduction. Curiously, studies of NPL sites estimate *lesser* impacts on property values than studies of non-NPL sites. This finding is consistent with expectations of greater funding and faster remediation at NPL sites. Faster action should elevate the present value of the site relative to sites where action is likely to be slower.

Policy Sites: Great Lakes Areas of Concern

Under the Great Lakes Water Quality Agreement of 1978, the United States and Canada designated forty-three sites in the Great Lakes Basin as priority areas for pollution remediation. These

Areas of Concern include twenty-six sites solely in U.S. waters, twelve Canadian sites, and five bi-national sites (http://www.epa.gov/glnpo/aoc/). The AOCs were designated primarily because they contain unusually high concentrations of toxic industrial chemicals (most commonly, polychlorinated biphenyls, or PCBs). Many also suffer from inadequately treated wastewater, pollution from nonpoint sources, and degraded habitat (Great Lakes Information Network 1995, U.S. EPA 1996).

Despite the expenditure of billions of dollars on AOC cleanup (Krantzberg et al. 1999, International Joint Commission 2003), by 2009 two Canadian sites and one U.S. site had been delisted. Two additional Canadian sites and one U.S. site had been recognized as Areas in Recovery. In 2005, a presidential task force estimated the cost of remaining remediation work in U.S. AOCs at $1.5 billion to $4.5 billion, depending on the level of cleanup (Great Lakes Regional Collaborative 2005). Table 2 summarizes the results of studies that examine the economic impacts at several of the AOCs. While seven AOCs have been the subjects of valuation studies, hedonic property value methods have been applied to only five.

Meta-Regression Functional Transfer

Model Calibration and Assumptions

Armed with the estimated transfer function, the next step is to calibrate the function to the policy sites. Our major imposed assumptions for the calibration are as follows: (1) Property types are limited to residential properties (*Residen* = 1); (2) Each of the AOCs encompasses multiple contaminated sites (*MSite* = 1); (3) One or more of the contributing waste sites in each AOC is included on the NPL (*NPL* = 1); (4) The average impacts apply only within a two-mile buffer around the boundary of an AOC; (5) The mean radial distance for the impact zone is 1.41 miles from the boundary of the AOC—this is the mean distance if homes are distributed uniformly within the two-mile radius; (6) Since all of the policy sites are aquatic and in the United States, Aquatic = 1 while Canada = 0; and (7) Following established practice (Rosenberger and Loomis 2003), the methodological variables (*Sample, IndSale, Demoecon, Access, Publish, Linear, Sig,* and *SAR*) are set equal to the mean values in the meta-analysis data set. These assumptions are reflected in the "Transfer Calibration" column of Table 1. Given these maintained assumptions, the calibration process effectively leaves only a single variable in the meta-function to distinguish between sites—the census region in which the waste site is located. This limitation will be addressed in the conclusions.

The application of the calibration process is illustrated for the Ashtabula River, OH AOC in the right-most column of Table 1. Summing together the coefficients in the column produces a net marginal proportional price effect (MPPE) of 7.785 percent. Multiplying this percentage times the census median home value in the Ashtabula River impact zone yields an average median impact of $5,585. Multiplying this number by the number of homes in the zone produces the total median price effect. The median home value and number of homes come from Table 3.

Application to Policy Sites

Table 3 lists the twenty-three policy sites of interest. We judge these AOCs to be best suited to the transfer methodology. Details about these sites can be found in Great Lakes Information Network (2005), International Joint Commission (2003), and the website of the Great Lakes National Program Office of the U.S. EPA (http://www.epa.gov/glnpo/aoc/). The delisted or recovering U.S. sites are so indicated with a footnote in Table 3.

Eight U.S. sites (Clinton River, Detroit River, Rouge River, Saginaw Bay, and St. Clair River, Michigan; and Black River, Cuyahoga River, and Maumee River, Ohio) are omitted from this list. The reason for the omission is that these AOCs either overlap extensively or encompass huge areas. The hedonic studies on which the meta-analysis transfer function is based rarely tackle such large and heterogeneous areas. Thus, we judged these AOCs to be "out of sample" and excluded them.

Three of the included AOCs—Buffalo River, NY, Sheboygan River, WI, and Waukegan Harbor, IL—have been studied in detail (Braden et al. 2004, Braden et al. 2008a and 2008b, Chatto-

Table 2. Economic Studies of AOC Economic Impacts

City	Method[a]	Payment Mechanism	Period Studied	Est. Average % Δ Real Estate Price	Geographic Coverage	Source
Hamilton Harbour, ONT	Relative real estate price changes	Residential real estate sales price trend comparison between Harbour area and elsewhere	1983–1996	~ 12%	2/3 mi. radius	Zegarac & Muir (1998)
Ashtabula Harbor, OH	Referendum survey	Tax increase to pay for cleanup	1997	Average $32.50 ~ 1%[a]	Ashtabula County, OH	Lichtkoppler & Blaine (1999)
Green Bay, Fox & Wolf Rivers, WI	SP, both 1) referendum & 2) open-ended	1) Tax increase to pay for cleanup; 2) Contribution to a fund to pay for cleanup	1997	Avg. $222/house/yr. *(est. ~2%)*[b]	State of Wisconsin[c]	Stoll, Bishop, & Keillor (2002)
Grand Calumet River, IN	RP – property values	Assessed residential real estate values as indicator of damage	2002	17%–27%	W/in 6 blocks; Low income; assessed values	McMillen (2006)
Waukegan Harbor, IL	1) RP–property values; 2) SP–Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	1999–2001[d]	Each method: 15%–20%	W/in 5 miles; CC estimates large value farther away	Braden et al. (2004), Chattopadhyay, Braden, & Patunru (2005)
Buffalo River, NY	1) RP–property values; 2) SP–Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	2003–2005	Hedonic method: 5% of of market value; Survey Method: 14% of market value	W/in 5 miles; CC estimates insensitive to distance	Braden et al. (2008a)
Sheboygan River, WI	1) RP–property values; 2) SP–Conjoint choice	1) Owner-occupied residential real estate prices as indicator of damage; 2) Hypothetical payment for homes if partial or full cleanup accomplished	2003–2005	Hedonic method: 7% of market value; Survey Method: 10% of market value	W/in 5 miles CC estimates insensitive to distance	Braden et al. (2008b)

[a] SP = stated-preference methods, usually surveys. RP = revealed preference methods, usually market transactions data.

[b] Percentage estimates not computed in original report; estimated here by computing present value of 30 years of annual payments at prevailing mortgage rates of interest in the year of the study, then dividing by median prices of owner-occupied homes as inferred from census data.

[c] County- and watershed-level results were not reported in the study.

[d] Some observations predated 1999.

Table 3. Selected AOCs and Data for Census Block Groups within 2 Miles[a]

AOC	No. Block Groups	No. Owner-Occupied Homes	Weighted Median Price (Yr 2000 $)
Ashtabula River, OH	18	4,478	$71,744
Buffalo River, NY	139	18,474	$67,684
Deer Lake, MI	18	5,184	$71,543
Eighteen Mile Creek, NY	1	373	$73,700
Fox River & Green Bay, WI	81	19,909	$103,009
Grand Calumet River, IN	190	37,238	$73,927
Kalamazoo River, MI	95	24,404	$90,960
Manistique River, MI	2	1,072	$49,954
Menominee River, WI	18	5,825	$53,972
Milwaukee Estuary, WI	615	124,585	$111,700
Muskegon Lake, MI	68	18,533	$78,590
Niagara River, NY	214	45,340	$78,823
Oswego, NY[b]	17	3,837	$73,283
Presque Isle Bay, PA[b]	41	7,845	$67,986
River Raisin, MI	15	3,391	$108,591
Rochester Embayment, NY	153	33,036	$85,482
Sheboygan River, WI	24	11,663	$88,710
St. Lawrence River, NY	15	3,463	$72,316
St. Louis River/Bay, MN/WI	160	46,660	$84,589
St. Mary's River, MI	14	3,917	$71,467
Torch Lake, MI	4	1,119	$42,051
Waukegan Harbor, IL	29	5,226	$110,243
White Lake, MI	7	2,852	$103,680

[a] Lists of included census block groups are available from the authors.
[b] Site has been delisted or declared an area in recovery.

padhyay, Braden, and Patunru 2005) and provide external validity checks for the transfer calibration. The two-mile buffer around the Buffalo River overlaps with the Niagara River impact zone, and the latter site is huge, but we have retained both of these AOCs in part to allow the external validity check. Our methodology for identifying block groups within the two-mile buffers assigns each group to only one of the two sites, thereby avoiding double counting. One other AOC, Grand Calumet River, IN, was the subject of an hedonic study of a very small residential area adjacent to the site (McMillen 2006). Relative to the methods used for forecasting at policy sites, the limited spatial scale of the Grand Calumet study complicates comparison.

We focus on the market value of owner-occupied residences. While other types of property could also be affected (Ihlanfeldt and Taylor 2003), it is difficult to obtain good aggregate data about their numbers and values. We rely on U.S. Census Bureau (2000) data for owner-occupied residences near the policy sites. Census reporting areas do not conform geographically to the impact zones as defined above. To achieve rough correspondence, we begin with U.S. EPA's geo-referenced maps of the AOCs (available from http://www.epa.gov/glnpo/aoc) and use geographic information system (GIS) software to delineate two-mile "impact zone" buffers surrounding each AOC perimeter. These maps are then overlaid on 2000 census block group maps from the U.S. Census Bureau (http://www.census.gov/geo/www/cob/index.html). Unique block group identifiers (which contain state, county, tract, and block group numbers) identical to those used by the Census Bureau allow the data to be joined to the shapefiles. Block groups with greater than 50 percent of their area within the two-mile buffers are identified using the *Buffer* and *Tabulate Area* tools in ArcMap (ArcMap GIS software, ESRI, Redlands, CA). This procedure includes some properties that lie outside the two-mile buffer and excludes some properties that lie within it. We assume these effects approximately offset one another—an assumption that is more plausible for the entire data set than for an individual AOC. Table 3 lists the number of block groups included for each AOC and the weighted median market value of the homes in those groups. The weights are based on the proportion of homes in each group.

The meta-analysis revealed that *PPE* varies from region to region. The policy sites occur in three different census regions: the New York and Pennsylvania sites are in the Mid-Atlantic region; the most westerly AOC, St. Louis River, straddles the West Northcentral and East Northcentral regions; and all other policy sites are in the East Northcentral region. In applying the transfer function, we vary the regional calibrations accordingly. Since St. Louis River straddles two regions, for this AOC, we set ENCent = WNCent = 0.5.

Results

To compute the nominal dollar impacts on property values within two miles of the AOCs, we multiply the estimated proportional price effect (PPE) by the number of owner-occupied houses and the weighted median property value. Table 3 lists the number of homes and the weighted average median dollar reduction in home prices. To illustrate the calculation, for Ashtabula the meta-analysis PPE = 7.785 percent. Multiplying this percentage by the year 2000 weighted median housing value of that area, $71,744, as shown in Table 3, we obtain a median projection of the property price impacts within two miles of the AOC: $5,585/home. Multiplying by the 4,478 owner-occupied homes within two miles of the AOC produces the total property value effect: $25.0 million.

This procedure is repeated for each included AOC. The results are reported in Table 4. The total estimated impact for all of the included AOCs sums to $3.8 billion in year 2000 dollar values. For comparison to the remediation cost estimates noted above, we adjust these values to year 2005 equivalents using metropolitan statistical area (MSA)-level indices (or state-level indices for AOCs not within an MSA) provided by the Office of Federal Housing Enterprise Oversight (OFHEO) (2009). The result is a total impact value of $5.3 billion in 2005 dollars.

All of the New York and Pennsylvania AOCs are in areas that have experienced substantial economic difficulties in recent decades, unlike the coastal portions of the Mid-Atlantic region. In this respect, their property markets more closely resemble those of the low-growth East Northcentral states. If we apply the East Northcentral factor in lieu of the Mid-Atlantic coefficient to these sites, the results are: Buffalo River, $97.3 million; Eighteen Mile Creek, $2.1 million; Niagara River, $278.2 million; Oswego River, $21.9 million; Presque Isle Bay, $41.5 million; Rochester Embayment, $219.8 million; St. Lawrence River, $19.5 million. The estimate of cumulative impact would decline to $2.9 billion in 2000 dollars, equivalent to $4.2 billion in 2005 dollars.

Discussion and Conclusions

One measure of the reliability of the transfer procedure is to compare the estimates it produces to those of detailed, site-specific hedonic studies. The candidate studies are listed in Table 2. Because of differences in the methods and assumptions, such comparisons are not easily made. In addition, it should be understood that the detailed studies used for these comparisons were included in the data set underlying the meta-function estimation; the two sets of results are not independent of each other.

We limit the comparisons to studies that used hedonic property value methods, on which our meta-transfer function is based. One such study,

Table 4. Estimated Residential Property Value Effects by AOC & Total, Year 2000

AOC	PPE (%)	Weighted Median Price Impact (Yr 2000 $)[a]	No. Owner-Occupied Homes	Total Median Price Effect (M Yr 2000 $)
Ashtabula River, OH	7.785	$5,585	4,478	$25.0
Buffalo River, NY	17.622	$11,927	18,474	$220.3
Deer Lake, MI	7.785	$5,570	5,184	$28.9
Eighteen Mile Creek, NY	17.622	$12,987	373	$4.8
Fox River & Green Bay, WI	7.785	$8,019	19,909	$159.7
Grand Calumet River, IN	7.785	$5,755	37,238	$214.3
Kalamazoo River, MI	7.785	$7,081	24,404	$172.8
Manistique River, MI	7.785	$3,889	1,072	$4.2
Menominee River, WI	7.785	$4,202	5,825	$24.5
Milwaukee Estuary, WI	7.785	$8,696	124,585	$1,083.4
Muskegon Lake, MI	7.785	$6,118	18,533	$113.4
Niagara River, NY	17.622	$13,890	45,340	$629.8
Oswego River/Harbor, NY [b]	17.624	$12,915	3,837	$49.6
Presque Isle Bay, PA[b]	17.622	$11,980	7,845	$94.0
River Raisin, MI	7.785	$8,454	3,391	$28.7
Rochester Embayment, NY	17.622	$15,064	33,036	$497.6
Sheboygan River, WI	7.785	$6,906	11,663	$80.5
St. Lawrence River, NY	17.622	$12,744	3,463	$44.1
St. Louis River/Bay, MN/WI	4.621	$3,909	46,660	$182.4
St. Mary's River, MI	7.785	$5,564	3,917	$21.8
Torch Lake, MI	7.785	$3,274	1,119	$3.7
Waukegan Harbor, IL	7.785	$8,582	5,226	$44.9
White Lake, MI	7.785	$8,071	2,852	$23.0
TOTAL				**$3,751.3**
Mean	10.641	$8,312	18,627	$163.1
Std.Dev	4.766	$3,598	27,219	$254.8
Std.Err	0.994	$750	5675.46	$53.1
95% Upper Conf. Limit	12.589	$9,869	$30,398	$273.3
95% Lower Conf. Limit	8.693	$6,756	$6,856	$52.9

[a] Calculated as the product of the PPE and the weighted mean price from Table 3.

[b] Site has been delisted or declared an area in recovery.

by McMillen (2006), addressed properties within just a few blocks of the Grand Calumet, IN AOC. The very small geographic scope of this study makes it difficult to compare to our analysis. Another, by Zegarac and Muir (1998), is based on Canadian data and therefore cannot be compared.

Braden and colleagues used hedonic property value methods in studies of Buffalo River, NY (Braden et al. 2008a); Sheboygan River, WI (Braden et al. 2008b); and Waukegan Harbor, IL (Braden et al. 2004, Chattopadhyay, Braden, and Patunru 2005). All of these studies focused on properties within five miles of the AOCs. The Buffalo study is most easily compared to the results in this paper. The authors found that 4,721 properties within 1.5 miles of the Buffalo River AOC sustained approximately $61.5 million in price discounts due to the AOC. This estimate was in year 2004 housing values. Using an OFHEO (2009) price index for the Buffalo, NY MSA, the year 2000 equivalent value is $52.8 million. A proportional adjustment to the number of homes in our analysis, 18,474, produces a value impact of $206.6 million. The correspondence to the estimate from our transfer approach, $220.3 million in year 2000 dollars, is remarkable. This piece of evidence suggests that the Mid-Atlantic calibration factor may in fact be appropriate for Buffalo. On the other hand, the match may be merely fortuitous since the meta-functional transfer estimate reflects median values while Braden et al. base their estimate on the mean value of actual sale prices. Of course, if property values are relatively homogeneous in the policy area, the median and mean should not be very different.

For Sheboygan River, Braden et al. (2008b) estimated an average percentage impact of 7 percent and a total value reduction of $157 million for 16,724 homes. Adjusting proportionally for fewer homes in the smaller impact area used here, and for price changes between 2000 and 2004, produces a year 2000 estimated impact of $51.1 million. Our method produced a somewhat larger percentage impact, 7.8 percent, and a total impact of $80.5 million. The difference in the percentage impact estimates accounts for more than one-quarter of the discrepancy.

For Waukegan Harbor, Braden et al. (2004) and Chattopadhyay, Braden, and Patunru (2005) found a price discount on the order of 15 percent, equivalent to approximately $450 million in 2001 dollars for 15,697 homes. Here, we applied the regional impact percentage, 7.8 percent, to 5,220 homes near the harbor and estimated the impact at $44.9 million in year 2000 dollars. Adjusting proportionally for the number of homes and price increases from 2000 to 2001 in the Chicago MSA reduces the larger estimate to approximately $127 million. The nearly 100 percent difference between the percentage impacts estimated regionally versus those derived from site-specific studies accounts for 80 percent of the discrepancy in the impact values.

It is reassuring that the estimates produced here are either similar to those produced by the site-specific studies or that the reasons for the differences are reasonably apparent. Of course, the lack of independence between the meta-function estimation and the comparison sites contributes to this outcome. The need for the meta-function to aggregate by region and distill a summary statistic for the regional percentage impacts is a substantial source of the deviations between the two classes of estimates.

We set out to learn how well functional benefits transfer would work in the context of hedonic property valuation of economic externalities. From this experiment, we draw several conclusions.

First, the meta-analysis yields surprisingly few variables that can be used to differentiate between the policy sites. Only two candidates presented themselves: the type of site and the region. Since all of the policy sites were of one type, the transfer methodology left only a single differentiating variable within the meta-function. Of course, this is not to overlook the value that is provided by the estimates of the other meta-function variables that do not differ between sites, but it does point out the challenge of finding variables that can be quantified in the meta-analysis as well as for the policy sites.

Second, and related to the first point, by relying on the meta-analysis's regional-level statistical representation of the relationship between AOCs and property values, the methodology necessarily averages away some of the differences between AOCs within regions. As noted by Kiel and Williams (2007), some of the AOCs undoubtedly have affected values more than others.

Third, due to spatial aggregation, the use of census data for identification of affected properties provides inexact counts.

Fourth, the methodology does not distinguish sharply between areas where the hedonic assumption of market equilibrium does or does not apply. An outstanding example of this potential problem is the Milwaukee Estuary, WI. The Milwaukee Estuary AOC includes a harbor area plus miles of tributary streams that wind through the city. Virtually the entire city, plus portions of adjacent municipalities, is included in the two-mile buffer. The AOC could therefore have pervasive effects on the property market. However, the underlying hedonic methodology assumes that the price effects are marginal in nature within a static equilibrium.

It would be irresponsible to use the methodology outlined here to predict percentage or dollar value gains that specific communities might anticipate from remediation. Largely because the meta-function has limited capacity to differentiate between sites, the scientific scaffolding is simply not yet available to carve such monuments. Furthermore, the fact that property values are reduced for properties close to AOCs does not necessarily mean that remediation and delisting will lead to the recovery of those values.

References

Braden, J.B., A.A. Patunru, S. Chattopadhyay, and N. Mays. 2004. "Contaminant Cleanup in the Waukegan Harbor Area of Concern: Homeowner Attitudes and Economic Values." *Journal of Great Lakes Research* 30(4): 474-491.

Braden, J.B., L.O. Taylor, D. Won, N. Mays, A. Cangelosi, and A.A. Patunru. 2008a. "Economic Benefits of Remediating the Buffalo River, NY Area of Concern." *Journal of Great Lakes Research* 34(4): 631-648.

Braden, J.B., L.O. Taylor, D. Won, N. Mays, A. Cangelosi, and A.A. Patunru. 2008b. "Economic Benefits of Remediating the Sheboygan River, WI Area of Concern." *Journal of Great Lakes Research* 34(4): 649-660.

Braden, J.B., X. Feng, and D. Won. 2009. "Waste Sites and Property Values: A Meta-analysis." Unpublished manuscript, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, Urbana, IL. A copy of this manuscript is on file with the authors.

Chattopadhyay, S., J.B. Braden, and A.A. Patunru. 2005. "Benefits of Hazardous Waste Cleanup: New Evidence from Survey- and Market-based Property Value Approaches." *Contemporary Economic Policy* 23(3): 357-375.

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(2): 311-326.

Faber, S. 1998. "Undesirable Facilities and Property Values: A Summary of Empirical Studies." *Ecological Economics* 24(1): 1-14.

Great Lakes Information Network. 2005. *Beneficial Uses in the Great Lakes Areas of Concern.* Available at http://www.great-lakes.net/envt/pollution/benefuse.html (accessed May 31, 2005).

Great Lakes Regional Collaborative. 2005. *Great Lakes Regional Collaboration Strategy*. U.S. EPA, Great Lakes National Program Office, Chicago, IL. Available at http://www.glrc.us/strategy.html (accessed January 11, 2010).

Greenstone, M., and J. Gallagher. 2008. "Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program." *Quarterly Journal of Economics* 123(3): 951-1003.

Ihlanfeldt, K.R., and L.O. Taylor. 2003. "Externality Effects of Small-scale Hazardous Waste Sites: Evidence from Urban Commercial Property Markets." *Journal of Environmental Economics and Management* 47(1): 117-139.

International Joint Commission. 1978. *Great Lakes Water Quality Agreement (Rev.).* Ottawa, Ontario, Canada and Washington, D.C. Available at http://www.ijc.org/en/activities/consultations/glwqa/agreement.php (accessed October 13, 2009).

International Joint Commission. 2003. *The Status of Restoration Activities in the Great Lakes Areas of Concern: A Special Report.* Windsor, Ontario, Canada. Available at http://www.ijc.org/php/publications/html/aoc_rep/english/report/pdfs/chapter1-e.pdf (accessed January 11, 2010).

Kiel, K.A. 1995. "Measuring the Impact of the Discovery and Cleaning of Identified Hazardous Waste Sites on House Values." *Land Economics* 74(4): 428-435.

Kiel, K.A., and M.A. Boyle. 2001. "A Survey of House Price Hedonic Studies of the Impact of Environmental Externalities." *Journal of Real Estate Literature* 9(2): 117-144.

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(1): 170-192.

Krantzberg, G., J. Hartig, L. Maynard, K. Burch, and C. Ancheta. 1999. "Deciding When to Intervene." International Joint Commission, Great Lakes Water Quality Board, Sediment Priority Action Committee. Windsor, Ontario, Canada. Available at http://www.ijc.org/php/publications/html/sedwkshp/index.html (accessed January 11, 2010).

Lichtkoppler, F.R., and T.W. Blaine. 1999. "Environmental Awareness and Attitudes of Ashtabula County Voters Concerning the Ashtabula River Area of Concern: 1996-1997." *Journal of Great Lakes Research* 25(3): 500-514.

McCluskey, J.J., and G.C. Rausser. 2003. "Stigmatized Asset Value: Is it Temporary or Long-term?" *Review of Economics and Statistics* 85(2): 276-285.

McMillen D.P. 2006. "The Benefits of Environmental Improvements in a Low-income Area: The Grand Calumet River Dredging Plan in Gary Indiana." In: J. Carruthers and B. Mundy, eds., *Environmental Evaluation: Interregional and Intraregional Perspectives*. Burlington, VT: Ashgate, pp. 147-162.

Office of Federal Housing Enterprise Oversight. 2009. House Price Index Data, 4Q 2008 Manipulatable Data for the Metropolitan Statistical Areas (MSAs) and 4Q 2008 Manipulatable Data for the Individual State Index. Available at http://www.ofheo.gov/hpi_download.aspx (accessed April 20, 2009).

Rosenberger, R.S., and J.B. Loomis. 2003. "Benefit Transfer." In P.A. Champ, K.J. Boyle, and T.C. Brown, eds., *A Primer on Nonmarket Valuation*. Dordrecht/Boston: Kluwer.

Simons, R.A. 2006. *When Bad Things Happen to Good Property*. Washington, D.C.: Environmental Law Institute.

Simons, R.A., and J. Saginor. 2006. "A Meta-analysis of the Effect of Environmental Contamination and Positive Amenities on Residential Real Estate Values." *Journal of Real Estate Research* 28(1): 71-104.

Stanley, T.D. 2001. "Wheat from Chaff: Meta-analysis as Quantitative Literature Review." *Journal of Economic Perspec*tives 15(3): 131-150.

Stoll, J.R., R.C. Bishop, and J.P. Keillor. 2002. *Estimating Economic Benefits of Cleaning Up Contaminated Sediments in Great Lakes Areas of Concern.* Madison, WI: University of Wisconsin Sea Grant Institute.

Taylor, L.O. 2003. "The Hedonic Method." In P.A. Champ, K.J. Boyle, and T.C. Brown, eds., *A Primer on Nonmarket Valuation*. Dordrecht/Boston: Kluwer, pp.331-393.

U.S. Census Bureau. 2000. *United States Census 2000.* American Fact Finder Summary File 3. Available at http://factfinder.census.gov/home/saff/main.html?_lang=en (accessed April 20, 2000).

U.S. Environmental Protection Agency (U.S. EPA). 1996. *Superfund Today*. Washington, D.C. EPA 540-K-96/004.

U.S. Environmental Protection Agency (U.S. EPA). 2009. "Legacy Act Projects Tackle Great Lakes Pollution." Great Lakes National Program Office, Chicago, IL, January. Available at http://www.epa.gov/glla/glla-factsheet-200901.pdf (accessed January 11, 2010).

Zegarac, M., and T. Muir. 1998. "The Effects of RAP Related Restoration and Parkland Development on Residential Property Values: A Hamilton Harbour Case Study." Burlington, ONT: Environment Canada.