Health Consultation

HUDSON RIVER PCBs

RESIDENTIAL PROXIMITY TO THE HUDSON RIVER AND
HOSPITALIZATION RATES FOR
ISCHEMIC HEART DISEASE AND STROKE: 1990-2005

Westchester, Rockland, Putnam, Orange, Dutchess, Ulster, Columbia,
Greene, Rensselaer, Albany, Washington and Saratoga Counties,
New York

EPA FACILITY ID: NYD980763841

Prepared by:
The New York State Department of Health

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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Center for Environmental Health
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EXECUTIVE SUMMARY

Background: In October 2006, Member of Congress Maurice Hinchey requested that ATSDR conduct a health consultation to assess cardiovascular disease among people residing near the Hudson River. A 200-mile segment of the Hudson River from Hudson Falls south to New York City is a National Priorities List (NPL) (Superfund) site due to contamination of the river with polychlorinated biphenyls (PCBs) from GE sites in Hudson Falls and Ft. Edward. In support of his request, Member of Congress Hinchey cited three studies of cardiovascular hospitalizations conducted with similar data and methods. These 2004-2005 statewide studies suggest residents of ZIP codes containing hazardous waste sites with persistent organic pollutants (POPs) such as PCBs have elevated risk for hospitalizations for cardiovascular disease, including ischemic heart disease, stroke and hypertension. Analyses conducted separately for ZIP codes next to the Hudson River suggest residents of these specific ZIP codes also have increased rates of hospitalization for cardiovascular disease.

In response to Congressman Hinchey's request for follow-up of the 2004-2005 findings for the Hudson River area, ATSDR and NYS DOH agreed to conduct a similar group-level study, but at a different level of geography, the Census block group. By using a level of geography that is generally smaller in area and population than a ZIP code, this follow-up seeks to more accurately adjust for socio-economic and other factors that affect cardiovascular hospitalizations and to improve upon the geographic classification of relative distance to the Hudson River. The follow-up investigation's analyses are restricted to the twelve counties abutting the Hudson River, from Washington County south to Westchester County. Within the study area's twelve counties, cardiovascular hospitalization rates in areas closest to the Hudson River are compared with rates in areas farther from the river.

Objectives: The follow-up investigation's specific objectives are to:

- increase the study's ability to control for confounding by socio-economic status through the use of block groups rather than ZIP codes as the unit of analysis;
- compare hospitalization rates among residents of block groups nearest the Hudson River to those among residents of block groups farther from the Hudson River; and
- compare the findings of this review to those of the earlier studies.

Methods: This study examines CVD hospitalization rates and residence near the Hudson River in the 12 counties abutting the Hudson River below Hudson Falls from 1990 through 2005. The hospitalization data for ischemic heart disease and stroke were acquired from the NYS DOH Statewide Planning and Research Cooperative System (SPARCS), established in 1979 to collect detailed records on discharges from hospitals located in New York State Statewide. U.S. Census data at the block group level from 1990 and 2000 were used to calculate the number of people in each race, sex, and age group for the study years.

Classification of the population into potential exposure categories was based exclusively on location relative to the Hudson River. Two types of exposure proxy categories were developed, block group adjacency and block group centroid distance to the river shore. For the adjacency categories, the hospitalizations were assigned to the adjacent category if the residential address was in a block group directly abutting the Hudson River. For the distance categories, block group centroid (population-weighted) distance to the river shore was used to assign hospitalizations in each block group to one of three categories: less than one-half mile from the Hudson River (closest), between one-half to one mile (close) from the river, and farther than one mile from the river (distant). Multivariable regression analyses were conducted to compare rates of hospitalizations among the exposure categories assigned at the block group level. These analyses controlled for age, sex, and race using individual-level data, and population density, percent Hispanic, median income, education, and distance to the nearest hospital at the block group level.

Results: The use of block groups resulted in 2,371 block groups as the units of analysis for the study rather than the 368 ZIP codes in the 12-County study area. The average population per block group in the study area is 1,200 compared to average population of 8,000 per ZIP code. The smaller geographical area and smaller populations in block groups contributed to improving the accuracy of the assignment of income and other group-level demographics to the hospitalizations included in the study and enhancing control for confounding by socio-economic status. (Tables 8a and 8b)

The study's multivariable analyses showed relatively small but statistically significant elevations of CVD hospitalization risk for residents of block groups categorized as adjacent, in close and closest proximity to the Hudson River. There is no evidence that residents of the closest block groups (less than ½ mile) had higher hospitalization rates than residents of the close block groups (between ½ to 1 mile). If there were a strong association between exposures from living near the river and the risk of CVD hospitalization, such a "dose-response" might have been shown by the analyses.

The data showed strong, statistically significant, associations between CVD risk and socio-economic status. To enhance the control for socio-economic status, separate analyses for each income quartile were conducted. These stratified analyses showed that residence in block groups near (close, closest or adjacent to) the Hudson River was associated with increased risk for CVD hospitalizations among residents of lower income block groups. Conversely, residence in block groups near the Hudson River was associated with decreased risk for CVD hospitalizations among residents of higher income block groups. In other words, in analyses that held income constant by looking only within the lower or higher income populations, living near the river shows opposite effects depending upon which income group is considered. The estimated increased and decreased risks are of sufficient magnitude to cancel each other out when average rate ratios for the four income quartiles are calculated. The average rate ratios can be interpreted as showing no evidence that hospitalizations among the general population are elevated for residents living near the river.

This type of group-level statistical analysis is not able to precisely identify the reason for these differing results. However, the strength and direction of associations among variables in the statistical models can be evaluated in light of known risk factors to suggest likely explanations. In this case, socio-economic status appears to be the most likely explanation for the findings. The strong association between socio-economic status and residential location (the indicator of potential exposure) and between socio-economic status and CVD hospitalization risk makes it likely that the small but statistically significant elevations shown in the multivariate models

(Tables 8a & 8b) are the result of the inability to completely control for socio-economic status' effects on CVD hospitalization risk. The strong effect of socio-economic status on residential location (exposure proxy) and on CVD hospitalization risk makes it likely that these overall multivariable regression results are affected by uncontrolled, i.e., residual confounding by socio-economic status.

Because of the similarities in study design and statistical analysis, the prior study's findings can be compared to some degree with the findings of the multivariate regression analyses in the current study. The major difference between the studies is the composition of the comparison areas for the analyses. Because of this difference, as well as other differences described in the report, the studies are not entirely comparable.

CVD hospitalization rate ratios estimated for living in block groups adjacent, closest, or close to the river in the current study are substantially lower than the rate ratios for residence in ZIP codes adjacent to the Hudson River in the previously published studies. In most cases the current analyses show elevations below 10% in contrast to elevations of 20% to 39% in the prior studies. The results of the current study are quite similar to the prior study results in terms of the associations reported for age, sex, race and income. These similarities and the general methodological similarities between the current and prior studies suggest the likelihood that the prior studies' findings also were affected by confounding by socio-economic status. .

Conclusions and Recommendations: While this type of study can neither prove nor disprove causal links among risk factors and health effects, it is useful for examining evidence for unusual patterns that might warrant additional investigation. This evaluation of hospitalization data, residential location and socio-economic factors in block groups in the 12 Counties abutting the Hudson River revealed a closely coinciding pattern of lower socio-economic status and residential proximity to the Hudson River, the proxy for potential exposure, and a strong association of lower socio-economic status and risk for CVD hospitalizations. The strong associations among residential location, socio-economic status, and CVD risk prevent us from drawing definitive conclusions from the multivariable regression analyses that showed modest but statistically significant elevations of CVD hospitalization risk for residents of block groups near the river.

To draw more definitive conclusions, particularly for outcomes such as CVD that are determined by multiple, known risk factors, studies seeking to investigate the role of PCB or POP exposures will require resource-intensive methods that include gathering individual-level exposure or biomonitoring information as well as medical histories and information on other risk factors.

This current investigation did not include environmental or biological sampling data. One study did gather such data in the Hudson River region with the highest potential exposures (Hudson Falls/ Fort Edward). This study detected a statistically significant reduction in the total PCB concentrations in outdoor air samples at a distance of 1200 meters (3/4 mile) from the river. However, the PCB levels in outdoor air in this area were lower than those in other communities with known PCB-contaminated sites, and similar to levels reported in other locations in the northeastern United States. The study found no detectable differences in study subjects' serum

PCB levels associated with proximity to contaminated portions of the river or other PCB sources. (Fitzgerald 2007, Palmer 2008).

It is recommended that the results of the current investigation of CVD hospitalization rates and residence near the Hudson River be shared with NYS residents and other stakeholders with interest in this issue and be submitted for publication in a peer-reviewed journal.

1. INTRODUCTION

The New York State Department of Health (NYS DOH) has a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) to perform environmental exposure and health assessments, conduct health statistics reviews, and perform epidemiological studies of populations in New York State which may have been exposed to environmental contaminants. In October 2006, Member of Congress Maurice Hinchey requested that ATSDR conduct a health consultation to assess cardiovascular disease among people residing near the Hudson River. A 200-mile segment of the Hudson River from Hudson Falls south to New York City is a National Priority List (NPL) (Superfund) site due to contamination of the river with polychlorinated biphenyls (PCBs) from GE sites in Hudson Falls and Ft. Edward. (See Appendix A for Member of Congress Hinchey's letter.)

In support of his request, Member of Congress Hinchey cited three studies (Sergeev and Carpenter 2005 [ischemic heart disease], Shcherbatykh et al. 2005 [stroke], Huang et al. 2006 [hypertension]). These statewide studies suggest residents of ZIP codes containing hazardous waste sites with persistent organic pollutants (POPs) such as PCBs have elevated risk for hospitalizations for cardiovascular disease, including ischemic heart disease, stroke and hypertension. Analyses conducted separately for ZIP codes next to the Hudson River suggest residents of these specific ZIP codes also have increased rates of hospitalization for cardiovascular disease.

These studies published in 2005-2006 are ecological studies. In an ecological study, data are analyzed by evaluating risk factors and health outcomes among groups. For example, rates of disease are compared for populations of ZIP codes with varying median income levels to see if income levels appear to be related to disease outcome rates. In these previously conducted studies, rates of hospitalization for residents of ZIP codes with hazardous waste sites containing POPs were compared with hospitalization rates for residents of ZIP codes without such waste sites to look for evidence that potential exposures might be impacting health outcomes. The studies report statistically significant elevations of cardiovascular disease hospitalizations in ZIP codes with POPs. For coronary heart disease and a subset, acute myocardial infarction, the study showed elevations of approximately 15% and 20% respectively (Sergeev and Carpenter 2005); for stroke, a 15% elevation (Shcherbatykh et al. 2005); and for hypertension, a 19% elevation (Huang et al. 2006), in ZIP codes containing waste sites with POPs compared with hospitalization rates in other New York State ZIP codes (excluding NYC) that did not contain waste sites with POPs (Table 1).

In sub-analyses in these studies, cardiovascular hospitalization rates for ZIP codes adjacent to the Hudson River were compared with cardiovascular hospitalization rates for ZIP codes in the rest of the state (excluding NYC) identified as not having inactive hazardous waste sites with POPs. These sub-analyses showed statistically significantly elevated hospitalization rates of 36% and 39% for coronary heart disease and the subset, acute myocardial infarction; a 20% elevation for stroke, and a 14% elevation for hypertension (Table 1). The Sergeev and Carpenter, Shcherbatykh et al., and Huang et al. articles state that the Hudson River ZIP codes are in an area where people have higher income, smoke less, exercise more and have healthier diets. This information is cited in these articles as evidence that known risk factors related to lower socio-economic status are likely not the cause for the elevated hospitalization rates in these Hudson River area ZIP codes.

In these previously published reports, Behavioral Risk Factor Surveillance System (BRFSS) data for entire counties are provided to support statements about the population of Hudson River ZIP codes having higher income and healthier lifestyles. However, because the ZIP codes adjacent to the Hudson River include only a proportion of the population of the counties abutting the river, these county-level BRFSS data may be misleading regarding characteristics of the ZIP codes adjacent to the river (Figure 1). In fact, data from the U.S. Census show that the ZIP codes adjacent to the river have lower median income than the counties within which they are located. The median income for the total population of the twelve counties adjacent to the Hudson River was $61,010 in 2000 while the median income for the ZIP codes adjacent to the river was $45,356. This median income for the population of the ZIP codes adjacent to the river is also slightly lower than the statewide (excluding NYC) median income of $47,735. (U.S. Census 2000) Thus, the Hudson River ZIP codes analyzed in the Sergeev and Carpenter, Shcherbatykh et al., and Huang et al. studies include a population of lower, not higher, socio-economic status compared to the rest of NYS (excluding NYC).

Because CVD and many CVD risk factors are associated with lower socio-economic status, it is especially important to adjust as much as possible for socio-economic status when conducting comparative analyses of CVD hospitalizations or disease incidence or prevalence. Regarding the hypothesis about POPs and CVD, research studies described in more detail below have suggested possible biological mechanisms for POP exposures' effects on the heart. There is very little research on human exposures to POPs and potential cardiovascular effects, however.

In response to Congressman Hinchey's request for follow-up of the 2004-2005 findings, ATSDR and NYS DOH agreed to conduct a similar study, also ecological, but at a different level of geography, the Census block group. By using a level of geography that is generally smaller in area and population than a ZIP code, this follow-up seeks to more accurately adjust for socio-economic and other factors that affect cardiovascular hospitalizations and to improve upon the geographic classification of relative distance to the Hudson River. In addition, rather than comparing hospitalizations among residents of Hudson River area ZIP codes to hospitalizations among residents of all other NYS (exclusive of NYC) ZIP codes with no waste sites with POPs, this follow-up investigation's analyses are restricted to the twelve counties abutting the Hudson river, from Washington County south to Westchester County. Within the study area's twelve counties, cardiovascular hospitalization rates in areas closest to the Hudson River are compared with rates in areas farther from the river. This more localized approach may also assist with reducing the potential impact of regional differences in medical care practice or reporting factors that could affect the hospitalization data (Ko et al. 2007). (Table 2 shows a more detailed listing of the methods used in the prior studies and follow-up study.)

Regarding environmental exposures, it is important to note that living near a hazardous waste site that contains PCBs or other POPs does not necessarily mean that human exposure from the site has occurred. Depending upon the conditions at a site, or the specific chemicals, exposures may be highly improbable. Information on body burden, for example, PCB levels in blood, or on levels of the chemical in off-site air, dust or soil is needed to support a claim of exposure. The studies published in 2005-2006 did not provide specific information such as environmental or biomonitoring data in support of the assumption that residence in ZIP codes containing hazardous waste sites with POPs or residence in ZIP codes adjacent to the Hudson River resulted in increased exposures to POPs in the population. For the purpose of this follow-up, we did not conduct environmental or human biological sampling to address this issue. Rather, this follow-up replicates the prior studies' approach with some enhancements to better control for confounding, particularly confounding by socio-economic status.

This descriptive epidemiologic investigation uses already existing hospitalization data from the Statewide Planning and Research Cooperative System and population data from the United States Census to evaluate comparative rates of cardiovascular hospitalizations. While this type of investigation can not show proof of cause and effect, it can assist in interpreting relationships among indicators of CVD burden and hypothesized exposures associated with distance from the Hudson River. This descriptive investigation may also assist in determining whether additional health investigations of these associations are warranted.

2. BACKGROUND

Cardiovascular Disease

The widely known risk factors for cardiovascular disease (CVD), in addition to age, sex, race, and family history, include tobacco use, high blood pressure, high serum cholesterol, alcohol use, obesity, low fruit and vegetable intake, physical inactivity, diabetes, low socio-economic status, mental ill-health, psychosocial stress and the use of certain medications (WHO 2010, NYS DOH 2009, Wing 1988, NYS DOH 2009a).

<u>CVD Definitions</u>: CVD is a general term for any disease of the circulatory system. The two main types of CVD are ischemic heart disease, also termed coronary heart disease, and cerebrovascular disease, also called stroke. Ischemic heart disease (IHD) results from restricted blood flow through the arteries supplying the heart muscle. The most serious risk from IHD is acute myocardial infarction (AMI), another term for heart attack. AMI occurs when blood flow to the heart is suddenly reduced or stopped, usually due to a blockage in a coronary artery. Angina is severe constricting pain in the chest, often radiating from the area immediately over the heart to the left shoulder and down the arm. Cerebrovascular disease refers primarily to stroke, the sudden impairment of brain function resulting from interruption of circulation to the brain. Ischemic stroke results from blockage of an artery supplying blood to the brain. Hemorrhagic stroke occurs due to the escape of blood from a ruptured artery supplying blood to the brain.

<u>CVD Burden and Trends</u>: CVD is the leading cause of death for men and women of all ages in the United States and in New York State. In 1999, for every death from IHD, there were five hospitalizations for ischemic disease in NYS (NYS DOH 2009a). Mortality rates from CVD have been declining steadily since the 1980's. Research studies estimate that approximately half of the decline is due to improved treatments for CVD and its risk factors such as high cholesterol and high blood pressure and approximately half is due to decreasing incidence of CVD. The decrease in incidence is due to trends in health behaviors, primarily reduced smoking rates.

CVD mortality rates do not appear to be declining for all segments of the population however, and may actually be increasing among some groups, particularly people of lower socio-economic status (Barnett et al, 1999). This may be due in part to higher rates of smoking among people of lower socio-economic status, as well as to other factors related to socio-economic status and race. A growing literature points to multiple causes for CVD and other health disparities including health practices, psychosocial stress, limited resources, discrimination, and access to health care. (Health United States 2007). Increases in the prevalence of diabetes and obesity in the general population partially offset advances in treatment and favorable trends for other risk factors. An increasing ischemic heart disease mortality rate in women ages 35 to 54 since 1997 is attributed to these unfavorable risk factor trends (Ford 2007, Lloyd-Jones 2009). New York State (NYS) and other northeast states have high IHD and low stroke mortality, with NYS having the highest IHD mortality and lowest stroke mortality among the 50 states (Howard et al. 2009).

CVD Data Sources: CVD mortality rates are more easily measured than incidence, prevalence, or hospitalizations because mortality data from vital records are a comprehensive and relatively accessible data source. Information for estimating the incidence and prevalence of CVD outcomes comes primarily from health interview, physical examination, and record surveys. Hospitalization data are available for NYS and the U.S., but are generally collected and analyzed in order to track trends in hospital care and resources expended. Actual CVD incidence data, validated by physician diagnosis, physician examination, or reviews of medical records, are not directly available for the entire U.S., or for specific geographic areas of NYS. Such information is available from population-based cohort studies that follow people over time in selected communities. While the concern underlying this research project is to understand CVD levels in the community, i.e., incidence and prevalence, we do not have data that directly provide us with this information. In the absence of such data, hospitalizations are frequently used as indicators of the burden of disease in communities, particularly in surveillance or hypothesis-generating investigations such as this one. In NYS, the Behavioral Risk Factor Surveillance System (BRFSS), an ongoing monthly telephone survey of adults aged 18 years and older, provides information about the burden of CVD by age, sex, race, income and education.

CVD Risk Factor Data: The BRFSS data for NYS show that over 20% of the population aged 65 and older reported having been diagnosed with CVD versus less than five percent of the population under 65. Males were slightly more likely to report having CVD than females. Non-hispanic whites compared to other ethnic groups combined were slightly more likely to report having CVD. None of these slight differences were statistically significant however. The only statistically significant demographic risk factors in the BRFSS data were low income and education levels. Statistically significant elevations of reported CVD were observed for respondents with incomes below $25,000 and respondents with a high school degree or less education. (NYS DOH 2009a).

Another factor that can affect the outcome measure, hospitalizations, is the likelihood of mortality prior to reaching the hospital. Studies show a variety of factors affect whether an individual experiencing a heart attack or stroke outside the hospital survives to be counted in hospitalization data. These factors include lack of knowledge about personal risk or prior disease, socio-economic status, race, marital status, and distance to the hospital (Galea 2007, Barnett 2006, Ayala 2003). Population-based studies report sudden cardiac death, usually outside the hospital, to be the first overt manifestation of heart disease for 40 to 60% of all cases (Kannel 1987, deVreede-Swagemakers 1997, UK Heart Attack Study 1998). An analysis of out-of-hospital mortality from AMI in Pennsylvania in 1998 showed that in relatively rural areas where travel time to the hospital was 25 minutes or longer, 72% of all AMI deaths occurred outside the hospital compared with a statewide average of 49% of AMI deaths occurring outside of the hospital (O'Neill 2003). In New York State, 55% of IHD deaths occur outside the hospital compared to 35% of stroke deaths (NYS DOH 2009b).

Hudson River PCB Contamination

During an approximate 30-year period ending in 1977, the General Electric (GE) plants in Hudson Falls and Fort Edward used PCBs in the manufacture of electrical capacitors and discharged large quantities of PCBs into the upper Hudson River. Estimates of the total direct discharges to the river are as high as 1,330,000 pounds. In 1983, the US EPA classified a 200-mile section of the Hudson River, from Hudson Falls to New York City, as a National Priority List site, making it one of the largest Superfund sites in the United States. In 2002, the US EPA issued a Record of Decision calling for targeted environmental dredging and removal of PCB-contaminated sediment in the upper River. (USEPA 2002) The dredging began in May 2009.

The Superfund environmental investigations and planned remedial actions have focused on the areas of the river near Hudson Falls and Fort Edward where the highest levels of PCBs in sediments are located. The 2002 Record of Decision provides information about the human health risk assessment, conducted for the Upper and Mid-Hudson, and the ecological risk assessment, conducted for the Upper and Lower Hudson River (USEPA 2002). Fish contamination and fish consumption are the primary concerns at the site.

In 1976, fishing was banned in the upper river and in 1995 a catch and release policy replaced the ban. NYS DOH continues to recommend people eat no fish from the Upper Hudson River, that children under age 15 and women of childbearing age eat no fish from the entire 200 mile stretch of river below Hudson Falls, and that the general population eat none of most species of fish caught between the federal dam at Troy and Catskill, approximately 40 miles south of Troy. The Lower Hudson remains closed to commercial fishing for striped bass and eight other species.

The fishing bans and advisories were issued because ingestion of fish is the major potential pathway for exposure for the general population. Many previous studies have shown relationships between consumption of fish from contaminated waters and human PCB levels. Another potential pathway for exposure, less frequently studied to date, is inhalation of PCBs. NYS DOH and ATSDR launched "The Hudson River Communities Project" in 2000 to address this issue. (More information on this project is provided below.)

POPS and PCBs

The category "persistent organic pollutants" (POPs) includes man-made chemicals that are by definition persistent in the environment. Examples of POPs are polychlorinated biphenyls

(PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychorinated dibenso-furans (PCDFs) and p,p'-diphenyldichloroethene (DDE), a breakdown product of the pesticide dichlorodiphenyltrichloroethane (DDT). These chemicals are stored in human fat tissues, accumulating over an individual's lifetime. They also accumulate in fish and other species, thereby concentrating up the food chain. Levels of most POPs measured in blood serum of Americans have decreased in the last few decades. An exception is polybrominated diphenyl ethers (PBDEs), levels of which have been increasing in recent years. While levels of many POPs are declining, a large number continue to be detectable in blood for most of the U.S. population. (USDHHS 2009)

This follow-up investigation focuses on the Hudson River where the POPs of concern are PCBs. PCBs are a group of synthetic chlorinated compounds manufactured in the U.S. through 1977. Production was halted due to concerns about the persistence of PCBs in the environment and the toxicity of PCBs shown in animal models. PCBs were used primarily by the electrical industry for capacitors and transformers and were also used in hydraulic fluids, fluorescent light fixtures, flame retardants, inks, adhesives, carbonless copy paper, paints, pesticide extenders, plasticizers and wire insulators. PCBs can be oily liquids or solids, and some are volatile and can exist as vapor in air. PCBs in the environment are generally mixtures of the many different types, known as congeners. (ATSDR 2000)

The variety of types of PCBs adds to the complexity of studying adverse animal and human health effects. Increasingly, PCB research focuses on specific PCB congeners and groups of congeners because specific types of congeners appear to have different mechanisms of action and toxicity. Dioxin-like PCBs (DLPCBs) are an important subset of PCBs due to concerns about their toxicity. The focus on dioxin-like PCBs is paralleled by increasing research on the group of POPs with dioxin-like properties. This type of PCB and POP research assigns toxic potency values relative to dioxin to various PCBs and POPs to provide an overall toxic equivalency value to specific PCB and other POPs.

From 2002 through 2007, NYS DOH and SUNY Albany School of Public Health researchers conducted the Hudson River Communities Study among residents of Hudson Falls and Fort Edward, the villages where the PCB discharges from two GE electrical capacitor plants occurred. The comparison community was upriver from the discharges, in Glens Falls. This study's evaluation of exposures included measuring PCBs in outdoor air and in blood serum. The study found that PCB levels in outdoor air were statistically significantly higher in the Hudson Falls/Fort Edward area (0.72 nanograms per cubic meter) than in the upriver Glens Falls area (0.40 nanograms per cubic meter), but that the PCB concentrations in the Hudson Falls/Fort Edward area were lower than those in other communities with known PCB-contaminated sites, and similar to levels reported in other locations in the northeastern United States. A statistically significant reduction in the total PCB concentrations in outdoor air samples was observed at a distance of 1200 meters (3/4 mile) from the river, from 0.760 ng/m^3 to 0.497 ng/m^3. (Fitzgerald et al., 2007, Palmer et al. 2008)

The average PCB concentrations in serum for the study and comparison populations did not differ significantly (3.07 ppb wet weight versus 3.23 ppb). The average toxic equivalency quantities (TEQ) for dioxin-like PCB congeners for the study and comparison area populations also did not differ. In addition, the study found no detectable differences in study subjects' serum PCB levels associated with proximity to contaminated portions of the river or other PCB sources. The study did find that lifetime consumption of Hudson River fish was associated with higher serum PCB levels (Fitzgerald 2007, Palmer 2008). Another recent biomonitoring study of Brooklyn, Manhattan and New Jersey fisherman who consumed versus those who did not consume their catch from the lower Hudson River and New York/New Jersey harbor suggests eating fish from these waters is not associated with an increased body burden of PCBs or most other organochlorines. This study did not address the inhalation pathway. (Morland 2008)

PCBs and Cardiovascular Disease Outcomes

Research studies on adverse health effects associated with PCB exposure have focused on many types of outcomes, organs and biological systems, including cancer, liver, reproductive and developmental effects, thyroid, endocrine, immune system and neurological effects, as well as specific effects on the skin and eyes. Relatively little research has focused to date on associations between PCB exposures and CVD outcomes. The majority of human studies have assessed health effects in occupational groups having relatively high-level exposures, among people consuming fish from contaminated waters, or people exposed to relatively high levels due to accidental contamination of food (USDHHS, NIH 2010)

PCBs have been shown to produce a variety of toxic effects in animals. These effects include cancer, allergies, hypersensitivity, damage to the central and peripheral nervous systems, reproductive disorders, and disruption of the immune system (ATSDR 2000). In contrast, research to date does not tell us whether specific types of human health effects have occurred from the low-level exposures experienced by the general population. Some human epidemiological studies of relatively low levels of PCDDs, PCDFs and PCBs suggest possible relationships not only with neurodevelopment of infants but also diabetes and a condition called insulin resistance, conditions that increase CVD risk (Longnecker 2001, Carpenter 2006, Arisawa 2005).

In 1998, a study of a population, in Seveso Italy, exposed to relatively pure TCDD (dioxin) from an industrial accident showed increased mortality from CVD, respiratory diseases and diabetes (Bertazzi 1998). These findings suggested the possibility that other dioxin-like chemicals, such as dioxin-like PCBs, might increase risk for these diseases. Some more recent animal studies described below suggest possible mechanisms of action for PCB effects that increase risk for CVD, diabetes and hypertension. Another relevant source of information is from research using the biological monitoring data from the National Health and Nutrition Examination Survey (NHANES) project to look at the association between PCB levels in blood and self-reported diabetes and heart disease. The body of evidence based on analytical human epidemiological studies remains relatively sparse however.

Some recent studies using NHANES biomonitoring data show associations between PCB levels and CVD (Lee 2006, Lee 2007, Ha 2007, Everett 2008). These studies are cross-sectional (comparisons at one point in time) evaluations of PCB levels measured in blood samples from individuals and self-reported CVD and diabetes, a risk factor for CVD. While these studies use individual-level biomonitoring and self-reported health outcome data, they are considered to be relatively weak in terms of providing evidence of causality because both exposure and outcome are measured at the same point in time. Given the nature of NHANES data collection and reporting practices, these studies are not able to control for possible geographical confounding which may occur if urban versus rural residence is associated with higher PCB levels and higher risk for CVD, for example. The higher PCB levels among African Americans in these data suggest urban residence may be playing a role in the PCB data.

The results of animal studies suggest multiple mechanisms by which PCB exposures could affect cardiovascular risk as well as multiple types of adverse health outcomes. One hypothesized mechanisms of action, specifically for dioxin-like PCBs is that they may have anti-estrogenic effects which impact CVD risk factors, such as serum cholesterol levels and blood pressure (Lind 2004). Several studies suggest PCBs interact with a specific receptor (AhR) and increase cellular oxidative stress, causing inflammation, cell injury and cardiovascular dysfunction (Hennig 2002). Similarly, some studies suggest PCB-induced inflammation of fat cells leads to obesity and increased risk for coronary artery disease (atherosclerosis) (Arsenescu 2008).

3. FOLLOW-UP STUDY DATA SOURCES AND METHODS

This follow-up investigation will provide perspective on the 2004-2005 findings (Sergeev and Carpenter 2005, Shcherbatykh et al. 2005) by producing results from analyses conducted at a more detailed level of geography, the block group rather than ZIP code, in order to better control for confounding. When the term confounding is used by epidemioogists, it refers to the problem that can arise when there is a factor, such as income level, that is not the factor of interest in the study, but that is related to the risk factor being studied (residential location – proxy for exposure) and to the disease being studied (CVD). This type of factor is labeled a “confounder” because it can confound, i.e, interfere with, or confuse, the evaluation of associations among the variables of interest in the data. All types of epidemiological studies face issues of confounding, but ecological, i.e. group-level, analyses face additional challenges related to potential confounding because analyses can not account for some important individual differences within the groups that are the units of analysis. (Morganstern 1998b, Hertz-Picciotto 1998). This investigation was able to control for each individual’s age, sex and race, but not for individual-level risk factors such as income or education level.

The follow-up investigation’s specific objectives are to:

- improve the ability to control for confounding by socio-economic status through the use of block groups rather than ZIP codes as the unit of analysis;
- compare the hospitalization rates among residents of block groups nearest the Hudson River to those among residents of block groups farther from the Hudson River;
- compare the findings of this follow-up study to those of the earlier studies;

Study Area and Exposure Areas

The overall study area is comprised of the 12 counties with geographic areas abutting the Hudson River south of the source of PCB contamination from the General Electric facility in Hudson Falls. The 12 counties are Westchester, Rockland, Putnam, Orange, Dutchess, Ulster, Columbia, Greene, Rensselaer, Albany, Washington, and Saratoga. U.S. Census boundaries are used to define the study area because census population estimates provide the data for the study area population's size and the population's age, sex and race distribution. Because the study period spanned 1990 through 2005 and populations change over time, 1990 and 2000 Census data were used to linearly interpolate the between-year populations from 1991 through 1999 for each block group. 2000 data were used without extrapolation to estimate block group populations from 2001 through 2005.

Because block group boundaries change between the Census years, 1990 block populations were normalized to fit 2000 block group boundaries before the estimation of sex, age and race group specific populations. In the digital map, 2000 block group boundaries were overlaid on the 1990 block centroids to assign 1990 block population counts to the corresponding 2000 block group boundaries. Then, 1990 block populations were summed to fit the block group boundaries. Next, population counts by age group (0-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75+), sex (male, female), and race (white, black, asian, other) were estimated for each year at the block group level. This investigation includes all ages over 25 years and the study population is divided into four race categories: white, black or African-American, Asian and "Other". The Pacific Island group was combined with the Asian group, and American Indian, "other," and "multiple races" categories are combined into a larger "other" category.

Classification of the population into potential exposure categories for this study is based exclusively on location relative to the Hudson River. Two types of exposure proxy categories were developed, block group adjacency and block group centroid distance to the river shore. For the adjacency categories, block groups were assigned to the adjacent category if they directly abutted the Hudson River, and all other block groups in the 12 counties were assigned to the non-adjacent category.

For the distance categories, a central point (centroid) within each block group was identified and used to assign block group centroid distance to the river shore. The block group centroids were population-weighted, which means the geographic distribution of households within 2000 census blocks were used to locate block group centroids based on the geographic population distribution. By locating a population-weighted block centroid rather than a more straightforward distance centroid, the assignment of block group distance to the river shore more accurately reflects distance to the river for the majority of block group residents. Buffers of one-half mile and one mile from the Hudson River boundary were created for the assignment of each block group into one of the three distance categories, less than ½ mile (closest), ½ to one mile (close), and farther than one mile from the river (distant).

Distance categories were selected, *a priori*, at the start of the study. Because environmental sampling data were not collected along the length of the river included in this investigation, we are not able to determine whether these distance categories represent actual differences in exposures. As discussed previously, a statistically significant reduction in the total PCB concentrations in outdoor air samples was observed at a distance of 1200 meters (3/4 mile) from the river, from 0.760 ng/m^3 to 0.497 ng/m^3 in a study conducted in the Hudson Falls/ Fort Edward area near the source of PCBs (Fitzgerald 2007, Palmer 2007).

For the adjacency categories, of the 2,371 block groups in the study area, 255 (11%) were classified as adjacent to the Hudson River and 2116 (89%) were classified as non-adjacent (Figure 2). For the distance categories, 225 (9%) were classified as closest to the river, 216 (9%) as close, and 1930 block groups (81%) as distant from the river.

Comparison of Figures 1 and 2 show that block groups include smaller geographic areas than ZIP codes, and that block groups are relatively smaller in area in urban versus rural areas. The study area includes a total of 368 ZIP codes compared to a total of 2,371 block groups. ZIP code average population in the study area is approximately 8,000 compared to block group average population of 1,200. Comparison of Figures 2 and 3 shows that using population-weighted centroid distance to the river produces different exposure areas than adjacency. Fifty-three (20%) of the adjacent block groups were categorized for the distance indicator as distant because the population in the block group was concentrated in the area farther than one mile from the river. On the other hand, about 11% of the 2116 non-adjacent block groups were classified as closest (77) or close (162).

Hospitalization Data

Hospitalizations for ischemic heart disease (IHD) and cerebrovascular disease (stroke) were included in this study. More specifically, hospital discharge records that listed as the principal diagnosis either IHD (ICD-9-CM: 410-414, and 429.7) or cerebrovascular disease (ICD-9-CM: 430-436) and subsets of each of these categories, similar to the subsets evaluated in the Sergeev et al and Shcherbatykh studies were included. The subsets are AMI and angina, subsets of IHD, and ischemic and hemorrhagic stroke, which are subsets of cerebrovascular disease (stroke). (Principal diagnosis represents the illness for which the person was admitted to the hospital.) Angina is an outcome not evaluated in the prior studies. It was added here for comparative purposes because it represents an outcome appropriately addressed by primary, outpatient, rather than inpatient hospital care. Angina is one of a group of outcomes included in the recently developed national "Prevention Quality Indicators" (USDHHS AHRQ 2007) as an indicator for geographic areas or populations for whom primary care is inadequate. Table 3 lists the specific ICD-9-CM codes and definitions included in this investigation.

While one of the previously published studies (Huang et al. 2006) showed elevations in hypertension (high blood pressure) rates, this outcome is rarely listed as the principal reason for hospitalization. As a secondary diagnosis, however, hypertension is extremely common, with substantial overlap with the primary diagnoses of IHD and stroke. In addition, hypertension hospitalizations were not as elevated in the ZIP codes adjacent to the Hudson River as the IHD and stroke outcomes. As a practical matter, geocoding the hypertension hospitalization data (1,364,000 hospitalizations) would overwhelm the resources for this project. For these reasons, hypertension was not included in this follow-up investigation

The source of the hospitalization data was the NYS DOH Statewide Planning and Research Cooperative System (SPARCS), established in 1979 to collect detailed records on discharges from hospitals located in New York State. Persons seen in the emergency department but not admitted are not included in the SPARCS data. Hospitalizations at U.S. Veterans Administration

Hospitals are also not included in this dataset. We identified the hospital transfers in the data and excluded them so that individuals are only counted once for the same event.

The NYS DOH Data Protection Review Board for SPARCS hospitalization data approved our use of hospitalization records for this investigation and provided approximately 460,000 records with a principal diagnosis of either IHD or stroke. Because of the large number of cardiovascular hospitalizations and this study's requirement for geocoding each hospitalized person's address, we selected a 50% random sample of the hospital discharges with principal diagnoses of IHD or stroke for inclusion in the study (229,948 records). Approximately one percent of these records (2,737) were eliminated from the study because they contained no residential address, resulting in 227,211 hospitalization records. 24,939 of these records were eliminated after geocoding because they were not within the 12 county study area. This left 202,272 records remaining in the study.

For geocoding to the block group level, the hospitalization street addresses were modified as needed using US Postal Service standards. The addresses were assigned geographic coordinates using commercially available geocoding software (MapMarker 2004). A combination of land parcel data and street centerline files were used to assign geographic coordinates. No contact was made with cases, parents, legal guardians or next of kin of cases to determine residential locations.

Once geographic coordinates were assigned to cases through address-matching, the case locations were overlaid onto digital maps of the study area using a geographic information system so that the number of observed cases falling within the study area boundaries could be determined and a 2000 Census block group could be assigned to each hospitalization. In order to protect confidentiality, no maps of individual case locations are provided. Geographic coordinates were not able to be assigned for some addresses, for example, rural routes or post office boxes. Internet searches were conducted for addresses that were located in facilities such as nursing homes, and trailer parks.

While fewer than one percent of records were missing sex or age information, approximately 15,000 records, seven percent, were missing race information. Evaluation of the geographic and temporal distribution of these records showed they were not randomly geographically distributed. 47% of the records with no race information were from one hospital; for that hospital, race was missing from 100% of the records in all years except one after 1997, mid-way through the study time-frame. Evaluation of other records missing race showed similar patterns of 100% of records missing race in specific years. In order to prevent biased hospitalization rate estimates, records missing race were assigned race randomly assuming a race distribution equal to that of the individual's residential block group.

Statistical Analysis

This investigation used negative binomial multivariable regression models, the statistical methods used in the previous studies (Sergeev and Carpenter, 2005 [IHD], Shcherbatykh et al., 2005 [stroke]). The follow-up study's analyses compared hospitalization rates for populations in block groups adjacent or in close proximity to the Hudson River to rates for populations more distant from the Hudson River while adjusting for the potential influence of other factors. Sex, age, and race-specific hospitalization count data comprise the dependent variable, and the statistical methods attempt to predict the counts using the sex, age, and race distributions from Census data as well as block group-level demographics such as median income. Models were first estimated using basic Census information for age, sex and race. Then, more fully adjusted models were estimated using information at the block group level for income, education, population density, Hispanic ethnicity, and distance to the nearest hospital.

More specifically, each hospitalized person's block group was used to assign quartile categories of block group median household income, % of population with less than a college education, population density, % of the population identified as Hispanic, and distance from the block group centroid to the nearest hospital. These variables were selected in advance. The population density variable was selected to account for potential effects on hospitalization rates of large differences in population density from the relatively rural northern counties to the more urban southern counties in the study area. % of the population identified as Hispanic was included because Hispanic ethnicity may be associated with CVD risk, but Hispanic ethnicity was not available in the hospitalization records. Distance to the hospital was included because studies show that shorter distances increase the likelihood that individuals with AMI and stroke survive to be admitted to the hospital.

As described previously, the literature about risk factors for CVD shows strong associations between lower income and education and higher CVD risk. Regarding the effects of income and education on hospitalization rates, the literature from analytic studies specifically of hospitalizations for CVD is quite sparse. Most analytic studies focus on prevalence, incidence or mortality in population-based studies or cohort studies, and there are not many of these. An example of a study that was useful as background is a study of income level and CVD mortality that showed strong associations of lower income and higher CVD mortality for men and women, with the relationship for men being linear throughout the range of income levels, while for women the relationship was only strong at levels of income below the median (Rehkopf 2008).

This follow-up study's approach was to use the same set of variables for the more fully adjusted models, using quartile cut points, for all the sex/race groups and types of CVD diagnostic subsets. The 2000 Census data were used to create the population-weighted quartile categories to be used in the statistical analyses. The quartile cut points are shown below:

	population density(persons per square mile)	median 1999 household income	% with less than a college education	% with Hispanic ethnicity	Hospital distance
Quartile 1	6.1 - <507	$2,499-<$40,968	0 - <31	0 - <2	<2.5 (median)
Quartile 2	507 - <102	$40,968 - <54,650	31 - <43	2 - <5	2.5 - <6 (50-75%)
Quartile 3	102 - <6,410	$54,650 - <72,944	43 - <55	5 - <10	6 – 11 (75-90%)
Quartile 4	6,410 - 94,372	$72,944 - 200,001	55 - 100	10 - 86	11 – 45 (90-100%)

SAS version 9 provided the statistical programs used to estimate hospitalization rates for exposure proxy categories and demographic categories. The models provide "contrast estimates," i.e., rate ratios, for one category versus a reference category of a variable and 95% confidence intervals (CI) for these rate ratios. For the location categories, rate ratios for the areas adjacent are compared to areas not adjacent to the river (reference) and areas closest and close to the river are compared to areas distant from the river (reference). If a rate ratio is greater than 1.00, the model has estimated an elevation of hospitalizations in that category of the study population compared to the reference population. If the rate ratio is less than 1.00 then there are fewer than expected hospitalizations compared to the reference population.

The magnitude of the elevation or deficit is also estimated by the rate ratio. For instance, if the hospitalization rate is twice as high in the adjacent population, it would result in a rate ratio of 2.00, while a 50% higher rate would result in a rate ratio of 1.50. If the hospitalization rate in the comparison group was only half as big as in the reference group, this would result in a rate ratio of 0.50. The 95% confidence interval assists with determining whether the observed differences are statistically meaningful, i.e., statistically significant. The confidence interval provides the range in which there is a 95% probability of including the true rate ratio.

In addition, to directly assess potential confounding, we examined the associations between income and exposure proxy categories, and between income and CVD hospitalization risk. Because the modeling process provides rate ratios that provide comparisons among groups but not the rates themselves, we also calculated the rates per population for each sex, race and income category in order to directly observe the relative magnitudes of CVD hospitalization rates. Finally, analyses stratified by income quartile were also conducted in order to assess the potential role of confounding by income. The stratified analyses consist of negative binomial regressions conducted separately for each quartile of income.

4. RESULTS

Demographics: Associations with Proximity to the River

Study Population: Table 4 provides detailed demographic characteristics for the total study population and the populations of the adjacent versus non-adjacent and nearer versus farther from the river block groups from the 2000 Census. The total population of the study area for this one year of the study time period, is 2,924,631 persons. The first row of Table 4 shows that approximately 11 percent of the study area population is classified as living in block groups adjacent to the Hudson River and 89% live in non-adjacent block groups. Approximately 8% of the study's population lives in the closest block groups, approximately 10% lives in close block groups and approximately 82% in distant block groups. The table also shows that approximately 81% of the total study population is identified as white, 9% black, 3% Asian, less than 0.1% Pacific Islander, 0.2% American Indian, 4% "other" and 2% "multiple races."

The 2000 Census data (Table 4) also show that the populations in block groups adjacent and non-adjacent to the river are similar in terms of the percent of minority population, but the adjacent block groups include a smaller percentage of persons who have attended college and a higher percentage of households below the poverty level. Median income is $47,320 for block groups adjacent versus $62,668 for block groups not adjacent to the river. Data for the study area from the 1990 Census show similar distributions (data not shown.)

For the distance to the river categories, there is a gradient for the three levels of distance from the river, with the closest block groups on average having higher percentages of minorities, smaller percentages of persons who have attended college and higher percentages of households below the poverty level (Table 4). The populations of the close and closest block groups are more similar to each other than to the populations of the distant block groups. The population of the closest block groups is estimated to be 19% black, close block groups, 14% black, and distant block groups, 8% black. The proportions for the "other" category used in the analyses, which includes multiple races and American Indians, are approximately 12% in both the closest block groups and in the close block groups compared to 5% in the block groups most distant from the river. Median income for the closest block groups is $40,748, close block groups, $44,962 and most distant block groups, $64,847.

The bar chart below illustrates the correlations between U.S. Census 2000 indicators of block group socio-economic status and block group centroid (population weighted) distance from the river for the study population.

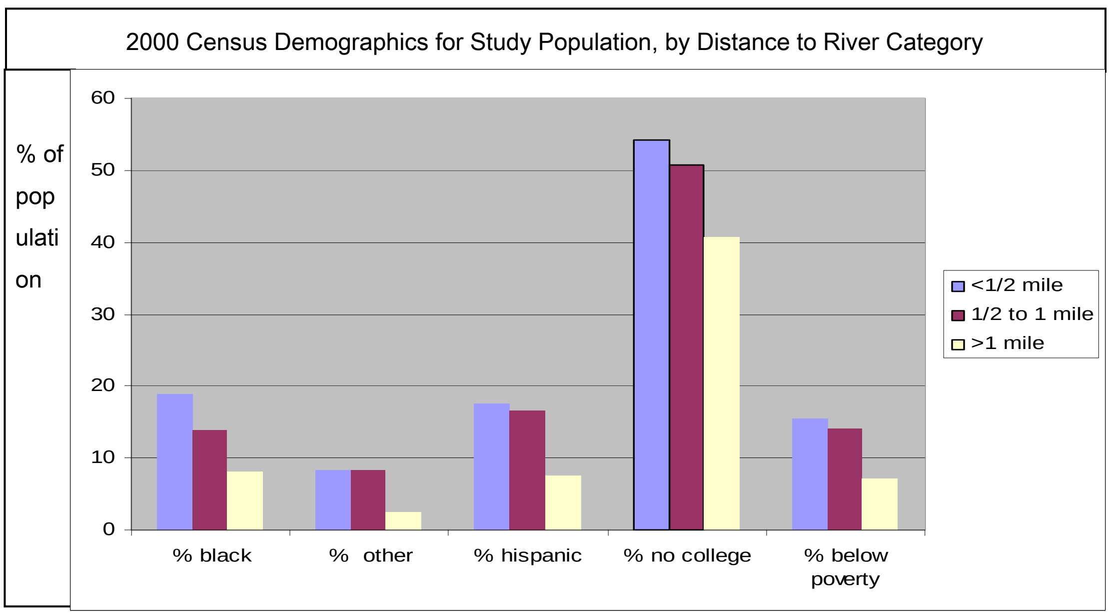

Table 5 shows selected demographic information for the person-year estimates used in the study analyses for the 1990-2005 study period. Person-year data represent individuals from Census estimates, counted repeatedly for each year of the study timeframe. As described in the Methods section, the estimation of person years used interpolation to account for population changes from 1990-2000 and techniques for taking account of block boundary changes. The person-years estimates for demographic categories (complete data not shown) show similar patterns as the 1990 Census data (data not shown) and 2000 Census data (Table 5). Table 5, for example, shows nearly identical percentages of population in each of the river distance categories as Table 4.

Table 5 also shows person year information for income quartiles and exposure proxy categories, as well as race and exposure proxy categories, that is consistent with the Table 4 data for the

2000 population. Table 5 row percentages show, for example, that while approximately 11% of the total study population live in adjacent block groups, approximately 19% of the population in the lowest income quartile live in adjacent block groups. By design, approximately 25% of the total study population is in each of the income quartiles. Table 5 column percentages show, however, that in the adjacent block groups, 41% of the population is in the lowest income quartile and only 9% are in the highest income quartile.

For the block groups within ½ mile of the river, the distribution among income quartiles is even more skewed towards the lowest income quartile. 61% of the population living within ½ mile of the river is in the lowest income quartile and only 6% is in the highest income quartile. Given that approximately 25% of the total study population is within each income quartile, these percentages indicate that living within the block groups closest to the river is associated with more than a doubling of the likelihood of being in a block group in the lowest socio-economic status quartile. 43.6% of those living in the block groups close to the river (1/2 to one mile from the river), are in block groups in the lowest income quartile. While less than a doubling, this indicates that living in the close block groups is associated with a 75% increase in the likelihood of being in the lowest quartile for socio-economic status.

<u>Hospitalizations</u>: Table 6 shows the process of removing hospitalization records from the study for a variety of reasons. The first column includes the 202,272 records that contained a residential address and were located within the 12-county study area, as described in the Methods section. The next five columns show the records remaining after data cleaning, exclusion of transfers, elimination of records with missing covariates and exclusions due to poor geocoding results. Approximately 33,000 records were eliminated because they were transfers from one hospital to another for the same event. For approximately 1,100 records, geocoding was inadequate for assigning block group for imputing race, as described in the Methods section. 336 records were missing sex (11) or age (325). Of the 167,733 records remaining, 154,220 (92%) were able to be adequately geocoded to a street address for assignment in a specific block group. While approximately eight percent of hospitalizations were eliminated due to inadequate geocoding, Table 6 shows that the percentages of hospitalization records for white, black, Asian and "other" categories and the distribution among diagnostic categories change very little after these records were dropped.

The final column of Table 6 shows that of the 154,220 hospitalizations in the analysis, 101,012 IHD hospitalizations comprise the largest health outcome category and are 65% of the hospitalizations in the study. AMI hospitalizations (35,811) account for 35% of the IHD hospitalizations and angina (4,731) accounts for five percent of the IHD hospitalizations. Stroke hospitalizations (53,208) comprise 34% of the study's hospitalizations. Approximately 36% of the stroke hospitalizations are for ischemic stroke (19,371) and approximately 11% are for hemorrhagic stroke (5,995).

Table 7 shows the distributions of hospitalizations among the four income quartiles. While each income quartile (by definition) contains approximately 25% of the study population, for all types of hospitalizations we see that the lowest income quartile includes more than 25% of hospitalizations, from a minimum of 28.6% (IHD) to a maximum of 35.6% of hospitalizations (angina). The highest income quartile includes fewer than 25% of hospitalizations for each CVD category, ranging from 18.2% for angina to 22.4% for hemorrhagic stroke. These deviations from the 25% quartile distribution show a strong linear pattern, with the largest percentage of hospitalizations coming from residents of block groups in the lowest income quartile and the smallest percentages coming from residents of the most wealthy block groups. For AMI, the lowest income quartile's share of hospitalizations is 50% higher than the highest income quartile's share of hospitalizations (30% vs 20%). IHD and stroke show similar differences, and angina shows a doubling, with the lowest income quartile contributing 36% of hospitalizations compared to the highest income quartile's 18% share of hospitalizations.

Table 7 also shows the distribution of hospitalizations among the race categories and the study population race category distribution for comparison. Blacks show lower percentages of IHD and AMI than their population percentages, and higher percentages of angina and stroke. While full presentation of race and sex findings is beyond the scope of this report, the lower than expected percentages of IHD and AMI among blacks, who on average have lower socio-economic status and are at greater risk for CVD hospitalizations, raised questions that were addressed by calculating hospitalization rates per 1,000 population for each sex and race group for each income quartile (Appendix B, Table 2). Figures 4, 5, and 6 show these rates for the white, black and Asian categories. (These rates for the "other" category are comparatively very high and are not shown on these graphs. This issue is addressed in the Discussion section.) Figures 4, 5, and 6 show the consistent and strong effects of income quartile on hospitalization rates for AMI and stroke for whites, blacks and Asians of both sexes. The other outcomes show similar patterns. (The "other" group showed an opposite pattern. [See Discussion Section])

Demographics Summary

The strong associations of lower income with residence closer to the river (Table 5) and lower income with higher hospitalization rates (Tables 7 & 8) create a difficult challenge for this investigation. The multivariable analyses of hospitalization rates attempt to control for socio-economic differences. However, because these income differences, which strongly affect hospitalization rates, are also strongly correlated with the gradations of exposure (river distance), it will be difficult to disentangle the influence of socio-economic status from the influence of potential exposures.

Statistical Analyses: Proximity to the River and CVD Hospitalization Risk

All the variables described above were included in the multivariable regression models and almost every quartile category for every variable showed statistically significant and expected types of effects for all the CVD hospitalization categories (Appendix B, Tables 1a and 1b). The following presentation of results focuses on the rate ratios for the exposure proxy variables. Table 8a (IHD) and 8b (stroke) show the regression modeling results. Results are shown first for models that include only age, sex and race in addition to the exposure proxy categories and second for models that also include median income, education, population density, Hispanic ethnicity and distance to nearest hospital. The tables provide numbers of hospitalizations and person-years to assist with interpretation. For example, for total IHD, we can see that while 10.8% of the study population lives in adjacent block groups, 12.2% of the hospitalizations are among people in adjacent block groups. This difference of 1.4 percentage points is the basis for the finding of a statistically significantly elevated rate ratio (risk) for IHD among people living in the adjacent block groups (RR=1.33, CI: 1.12-1.57).

Looking across the columns of Tables 8a and 8b, we can see the rate ratios for each of the outcomes for the adjacent versus non-adjacent block groups, and the results are similar to those for IHD. The elevated rate ratios range from 1.23 for angina to 1.36 for AMI. The only rate ratio not elevated in these first models, adjusting only for age, sex, and race, is for hemorrhagic stroke. Going down the rows of the Table, the next set of rate ratios are for the distance to the river categories. The findings are very similar to those for the adjacent block groups. Here, however, we have two exposure proxy categories, allowing comparison of the two. These rate ratios show no evidence that living in the block groups closest to the river (<1/2 mile to the river) produces greater risk than living in the block groups close to the river (1/2 to 1 mile from the river).

The next set of rate ratios are for models with additional adjustment for the demographics of each hospitalized person's block group as well as distance to the nearest hospital. As expected, adjustment for block group median income and other demographics accounts for some of the variability in hospitalization counts and thereby reduces the magnitude of the rate ratios estimated for the river adjacency and distance categories. The rate ratio elevation for total IHD, for example, is reduced from 1.33 to 1.07 (RR=1.07, CI: 1.04-1.11). The elevated rate ratios in these more fully adjusted models, for the adjacency analyses, are of similarly small magnitude, ranging from 1.06 for AMI to 1.10 for ischemic stroke. Four of the six outcomes show statistically significant elevations. Again, only hemorrhagic stroke shows no evidence of an elevated rate ratio.

For the river distance categories, none of the rate ratios show any evidence that living in the block groups closest to the river (<1/2 mile to the river) produces greater risk than living in the block groups close to the river (1/2 to 1 mile). Of the six types of outcomes, only two show statistically significantly elevated rate ratios for living in the closest block groups (total stroke and ischemic stroke). For the close block groups, four out of six outcomes show statistically significantly elevated rate ratios. The statistically significantly elevated rate ratios vary from 1.06 (AMI, stroke) to 1.13 (angina).

To address the strong evidence described earlier for confounding in these data, i.e., the association of lower income with both CVD hospitalizations and residence closer to the river, we also conducted the analyses separately for each quartile of income. These results are presented in Table 9. The first results are from analyses adjusting only for age, sex, and race, and the second set of results are from models including the additional demographic factors. For simplicity, rate ratios are shown only for block groups closest to the river, compared, as in the other models, to block groups farther than one mile from the river. (Results were similar for the other distance categories (data not shown).

For the two lowest income quartiles, Table 9 shows results similar to those for the study population as a whole (Table 8a, 8b). However, for the two highest income quartiles, which represent ½ of the study population, Table 9 shows a consistent pattern of reduced rate ratios for residence in the closest block groups, within ½ mile of the river. In the highest income quartile, these reduced rate ratios are statistically significant for almost all of the outcomes in both the partially and more fully adjusted models. In addition, the magnitude of the rate ratio estimates, i.e., their departure from 1.00, is relatively high. For the population living in block groups with the highest median income (income >$73,000), living within ½ mile of the river is associated with having about 70% of the risk for IHD, AMI and stroke (CI=0.68, 0.69, 0.69) as the population in equally high income block groups farther than one mile from the river. In other words, among the highest income quartile, living this close to the river is associated with an estimated 30% reduction in risk for these types of hospitalizations. For angina (CI=0.28), there is an estimated 70% reduction in risk, and for ischemic stroke (CI=0.58), the reduction is estimated to be 40%. These stratified analyses show that in one-half of the study population, the two higher income quartiles, there is no evidence of elevated hospitalization risk for populations in block groups closer to the river. On the contrary, reduced rate ratios are shown for all outcomes in the higher income quartiles for residents of block groups within ½ mile of the river compared to those living farther than one mile from the river.

Weighted average rate ratio estimates are a standard method for estimating a general population finding from stratified analyses, and are also provided in Table 9. These average rate ratios range from 0.78 to 1.02, showing no evidence of elevated risk, for the overall population, associated with residence within ½ mile of the river compared to living farther than one mile from the river. Results for the other categories of river proximity showed similar results (data not shown). (Given the evidence of confounding interfering with analyses of the entire study population and the opposing findings depending on income quartile, no confidence intervals are provided here for the overall population-weighted average estimates.)

Summary of Results

In summary, the multivariable regression results for the entire study population (Tables 8a, 8b) show statistically significantly elevated rate ratio estimates for the adjacent versus non-adjacent block groups for four out of six hospitalization diagnosis categories. The analyses also produce statistically significantly elevated rate ratio estimates for block groups closest to the river (less than ½ mile from the river) and close to the river (between 1/2 to 1 mile from the river) compared to distant block groups (farther than 1 mile from the river) for most of the outcome categories. However, the findings provide no evidence that the closest block groups have higher hospitalization rates than the close block groups.

The most elevated rate ratio estimate is 1.13 (angina), indicating an estimated 13 percent increase in risk for angina hospitalizations for residents of close versus distant block groups. The only outcome with no statistically significant elevations for living near (adjacent, closest or close) the river in the more fully adjusted models is hemorrhagic stroke. It is noteworthy that the outcome that is considered an indicator of inadequate primary care rather than of incidence or prevalence, angina hospitalizations, shows the highest elevations associated with residence near the river (Table 8a). In addition, the hospitalization outcome with the least association with socio-economic status in our data (Appendix B, Table 1b) and the lowest out-of-hospital mortality (NYS DOH2009b), hemorrhagic stroke, is the outcome that shows no pattern of elevations associated with residence near the river (Table 8b). This pattern of findings is consistent with the interpretation that the rate ratios for living closer to the river are reflecting the influence of lower socio-economic status and other known risk factors for hospitalizations for CVD rather than any unusual environmental exposures in areas near the river.

The stratified results add strong support to this conclusion. They suggest that classical confounding of the exposure-disease relationship by socio-economic status produced biased results in the overall multivariable regression analyses. While the regression analysis of the entire study population shows elevated hospitalization rates for residents of block groups near the river compared to residents living farther away (Table 8a and 8b), the stratified analyses (Table 9) show this association applies only to the 50% of residents living in block groups with lower median incomes. For the other 50% of residents, those who live in block groups with higher median incomes, hospitalization rate ratios are reduced for those living near the river. Classical confounding refers to the type of confounding that can occur in individual-level or group-level (ecological) studies when a factor such as socio-economic status affects both the exposure (residential location) and the health effect. In this study of CVD hospitalizations, there are disproportionate numbers of outcomes and exposures (residence near the river) among specific levels of the confounder, the lower income quartiles (Tables 4, 5, 7). The disproportionate numbers of hospitalizations and potential exposures (block groups close to the river) among the lower income quartiles create an artifactual, exaggerated, i.e. biased, effect on the estimates for the overall analysis. (Greenland 1999, Greenland 2003)

5. DISCUSSION

The key finding of this investigation is that the results of the multivariable regression modeling for the entire study population, the elevated CVD hospitalization rates for populations living closer to the Hudson River, are likely to be artifacts of classical confounding. Stratifying on the confounding variable, i.e., holding median income level constant, the standard method for controlling for confounding, showed the decisive role of income as a confounding variable. The associations between living closer to the river and having higher hospitalization rates were evident only for people in the two lowest income quartiles. For people in the two highest income quartiles, the association was completely opposite, i.e., people living closer to the river had lower rates of hospitalizations. This variability of effects can be interpreted as evidence that there are no actual effects of the exposure-proxy categories on hospitalization rates.

This type of classical confounding due to the strong influence of a variable that precedes, causes, or strongly affects both the exposure and the health outcome can occur in any type of epidemiological study. The ecologic, i.e. group-level, analysis in this study is not the primary cause of the confounding. Rather, the complex associations in the population among income, education, CVD risk, geographic residential patterns and geographic assignment of exposure status are the basis for the confounding. However, the study's group-level design contributes to the study's inability to completely control for confounding using multivariable regression methods and contributes to difficulties of interpreting the study findings.

The stratified results shown in Table 9 may also be a reflection of inadequate control for socio-economic status using quartile groupings. A possible explanation for the Table 9 findings is that among lower income quartile populations, people living in closest proximity to the river may have the lowest incomes, while in higher income quartile populations, people living in closest proximity to the river may have the highest incomes. This potential income difference associated with river distance within quartile groupings would explain why the stratified analyses showed positive associations with hospitalization risk for lower income residents closest to the river and negative associations with hospital risk for higher income residents closest to the river. In this example of a possible explanation, it is assumed that river proximity categories are capturing relative income (and hospitalization risk) differences rather than exposure. Because the exposure proxy, river distance categories are assigned at the group level, this type of analysis is not able to distinguish whether these categories are capturing income, rather than potential exposure, in the analyses.

When trying to interpret this study's findings, it is important to keep in mind the many factors associated with CVD risk that are not controlled for in this study's analyses. These include tobacco use, high blood pressure, high serum cholesterol, alcohol use, obesity, low fruit and vegetable intake, physical inactivity, diabetes, mental ill-health, psychosocial stress and the use of certain medications. Another factor that is not known to be associated with CVD risk, but that is relevant for PCB exposure is consumption of contaminated fish. It is possible that lower income populations are more exposed to PCBs because they are more likely to eat fish from the Hudson River. This, however, would not help explain why higher income people near the river showed lowered CVD hospitalization risk than their counterparts living farther from the river.

In addition to the confounding due to socio-economic status's effects on both the risk of CVD and residential location (the exposure proxy), there is the possibility that another pattern of effects, also associated with socio-economic status, called effect modification, plays a role in these data. Effect modification occurs when different groups, people with differing types of health insurance, or differing behaviors, for example, show different patterns or levels of health effects associated with the same exposures. The differing effects (CVD hospitalization risks) of residence in block groups closest to the river by income quartile could be interpreted as evidence of effect modification (Table 9). However, the magnitude and the change in direction of effects is unlikely to be due solely to differing biological or behavioral factors, associated with income level, that affect the results of exposures from living near the river. Given the strong associations of socio-economic status and CVD hospitalization risk, it is more likely that the analyses stratified by income enhance protection against bias compared to the multivariable models, and that the stratified analyses represent findings from better control for confounding as opposed to effect modification.

Effect modification is a concept used to describe important relationships between exposures and effects (that may differ among sub-groups, for example) that the researcher wants to identify and understand. Confounding, on the other hand, refers to associations among the variables that the researcher is trying to control so that the effects of interest (effects from exposures rather than age or sex, for example) can be identified and the strength of the effects can be estimated. The ecological design of this study contributes to the difficulty of interpreting whether the study shows evidence of effect modification as opposed to confounding. (Morgenstern 1998b, Hertz-Picciotto 1998).

Another limitation associated with this study's design is that block-group level socio-economic and environmental attributes that are assigned to individuals in this type of study can be more strongly correlated at the group level than at the individual level. In this way, the ecological assignment of variables may lead to increasing problems of confounding because of strong associations among indicators of socio-economic status and environmental exposure categories. (Morganstern 1998a) This problem is likely to have affected this study's results. As with effect modification by group, described above, this type of confounding by group cannot be evaluated with ecologic data because individual-level information is needed to check for this type of "cross-level" bias.

Ecological analyses are an important tool for environmental epidemiology and there is therefore a large and growing literature on their strengths and limitations and methods to address limitations (Piantadosi 1988, Greenland 1989, Greenland 1992, Greenland 1994, Richardson 2000). One particular concern is the interpretation of ecological study findings showing modest elevations of risk, such as in the current study, with rate ratios in the more fully adjusted models generally estimated to be below 1.10 (Wakefield 2003, Morgenstern 1998.) Wakefield states that slight elevations need to be interpreted with great caution ...

> in particular for cancer and heart disease, (because) there are risk factors that are far more predictive of disease than environmental factors … Consequently, the potential for confounding is strong, since ecological studies do not directly use individual-level risk factor data, although stratification by age and gender is routinely carried out. (Frequently an area-level measure of socio-economic status is also used as a confounding variable, but being an aggregate summary, it only provides very crude control). (Wakefield 2003, p. 9-10)

A strength of this study is that it used Census block groups which are relatively small, average population of 1,200 in the study area, to assign socio-economic characteristics rather than the larger ZIP codes, with average population size 8,000 in this area. By using block groups, this study sought to reduce confounding by socio-economic status because the assignment of median income and other variables at the block group level was expected to be more accurate, with block group populations expected to be more homogenous than larger and more geographically diffuse ZIP code populations used in the prior studies.

The use of census block groups rather than ZIP codes likely enhanced the accuracy of the group-level category assignments. However, this type of design that assigns characteristics to hospitalizations using group-level characteristics and distance to the river is limited in comparison to individual-level designs that gather such information from personal interviews, for example. Most importantly for this investigation, the group-level assignment of median income and other demographic variables to each hospitalization limited the study's ability to distinguish among individuals within the exposure proxy categories, and thereby reduced the study's ability to control for confounding.

This type of measurement error, or inaccuracy, from assigning group-level potential exposure, income, or educational level to the individual hospitalizations, is generally assumed to bias a study towards findings of no associations or no effects. But in situations where the measurement error is more severe for some variables than others and these variables are correlated, then the study findings can be biased either towards exaggerated effects or no effect. In this investigation, potential measurement error associated with the assignment of exposure categories based on block group centroid distance to the river is expected to be relatively low because a large proportion of the hospitalization addresses are very clearly in areas distant from the river. The measurement error associated with the assignment of group-level demographic characteristics (income and education, for example) from the Census is potentially relatively higher because this type of error can occur throughout every block group in the study.

Another strength of this study is the use of NYS SPARCS data, a relatively comprehensive, population-based source of information about hospitalizations. These data include individual-level information used in this study for patient address, sex, age, race and diagnosis. Of these variables, only the address and race categories were missing information for substantial numbers of records and this limitation could have contributed to imprecision sufficient to create bias in the findings. These issues are discussed in greater detail below.

While geocoding to block groups represents a strength of this study, this procedure required high quality address information. One percent of the study area's hospitalization records contained no address and eight percent of the addresses could not be accurately geocoded to a block group, resulting in nine percent of hospitalizations being eliminated from the study because of address and/or geocoding issues. The distributions of race categories and distribution among the types of diagnoses did not change after dropping records with no or insufficient address information, suggesting that the dropped records did not represent a substantially skewed group of records.

Inaccuracy in the study's assignments of race categories results from limitations associated with both the hospitalization and Census data. The SPARCS hospitalization database did not include information on race for seven percent of the study's hospitalizations. We imputed race by assigning race category randomly based on the race distribution of the person's block group. This method would have biased the study toward a finding of no effect of race on hospitalization risk.

Another limitation of the SPARCS data used in this investigation is that repeat hospitalizations for the same individual were not able to be identified. If an individual was admitted to the hospital many times over the course of the study period then that individual would be counted multiple times. This limitation may have contributed to an exaggerated association of lower socio-economic status and CVD hospitalizations because some people with lower incomes receive less adequate outpatient care and may have more repeat admissions. Because of the association of lower income with residence near the river, this limitation may have contributed to the difficulty of adequately controlling for confounding by socio-economic status in this investigation.

While the use of Census data at the block group level rather than at the ZIP code level is a strength in terms of relative homogeneity among the population within block groups, it is possible that block group population estimation errors contributed to imprecise estimation of hospitalization rates. Particularly with regard to the race categories, the study finding that the "other" category showed a counter-trend of higher income and higher CVD hospitalization rates (Appendix B, Table 2) is evidence that differences between the categories used in the Census race designations and hospitalization race assignments affected the estimated hospitalization rates. The evolving choices for identifying one's race in the Census are not concurrently reflected in the SPARCS data and these inconsistencies likely contributed to imprecision in the estimates of CVD hospitalization risk associated with specific race categories. These issues did not contribute to bias for the overall findings, however. We modeled the data with a variety of race category groupings, combining black and "other," for example, and the overall results did not change (data not shown).

Also regarding the Census, undercounting of approximately two percent for the U.S. population in 2000 was estimated to be primarily among the lowest socio-economic groups and minorities, while over-counting of one percent was estimated to have occurred among the most wealthy who sometimes received and completed forms at multiple residences (United States Census' Monitoring Board 2001). The undercounting of the lower income population would result in over-estimation of rates in this population. Undercounting of recent Asian immigrants, for example, particularly those of lower socio-economic status, is a potential reason for the relatively high rates of CVD hospitalizations estimated for lower income quartiles of the Asian population (Figures 4-6). Models that grouped the Asian population with other race categories were also estimated, and these showed the same results as the models reported here (data not shown). Undercounting of lower income groups in general would have contributed to the finding of higher hospitalization rates in these groups and added to the difficulty of adequately controlling for confounding of lower income with residence near the river.

This study used a 50 percent sample of the CVD hospitalizations in the study area. This was accomplished by using every other record provided in the complete dataset. This would be expected to provide a non-biased random sample. As a general check for data provision, management or analysis errors, we compared our estimates of hospitalization rates per population with those from other sources. Table 10 shows these comparisons and shows that our estimates are generally consistent with rates from other sources.

Actual exposures were not measured in this investigation. Rather, proximity to the river was used as a proxy for potential exposures associated with the river. In addition, other potential exposures that may impact CVD were not evaluated or measured. Exposures to lead and air pollution would be expected to be higher in more urban areas and areas near heavy traffic, which may tend to coincide with proximity to the river. These issues were not addressed in this investigation. If these exposures were occurring more often near the river and contributing to cardiovascular hospitalization rates, this would contribute to findings of elevations in areas closer to the river.

It is important to keep in mind the limitations associated with using CVD hospitalizations when incidence and/or prevalence of CVD are the actual outcomes of interest. As described previously, mortality prior to reaching the hospital may reduce hospitalization rates, particularly for AMI and stroke for some groups or areas more than others and introduce bias if hospitalizations are being interpreted as a surrogate for incidence or prevalence.

Addressing Study Objectives

This follow-up report has addressed the study's first two objectives, to increase control for confounding by socio-economic status through the use of block groups rather than ZIP codes as the unit of analysis and to compare the hospitalization rates among residents of block groups nearest the Hudson River to those among residents of block groups farther from the Hudson River. Regarding the first objective, the use of smaller units of analysis, block groups rather than ZIP codes, improves the accuracy of the assignment of income and other group-level demographic categories to the hospitalizations.

Regarding the study's second objective, to compare hospitalization rates among residents of block groups near to the river to hospitalization rates among residents far from the river, this study's multivariable analyses showed relatively small but statistically significant elevations of CVD hospitalization risk for residents of block groups in close proximity to the Hudson River. Stratified analyses that controlled for confounding directly by conducting analyses within each income quartile showed that residence in block groups near the Hudson River was associated with increased risk for CVD hospitalizations among residents of lower income block groups and, conversely, residence in block groups near the Hudson River was associated with decreased risk for CVD hospitalizations among residents of higher income block groups. The estimated increased and decreased risks were of sufficient magnitude to nearly cancel each other out when average rate ratios for the four income quartiles were calculated. The average rate ratios may be interpreted as showing no evidence that CVD hospitalization rates are elevated for residents living near the river, for the general study population. This finding suggests that the multivariable regression findings for the overall population show elevated risks for hospitalizations among residents of block groups near the river due to confounding of the relationship of residential location and CVD risk by socio-economic status.

The findings from analyses stratified by income quartile may also be interpreted as showing that residing in a higher versus lower income quartile block group produces different effects from similar exposures (effect modification). As discussed previously, the ecological, i.e., group-level, analyses are unable to directly evaluate confounding and effect modification. Rather, information about the strengths and direction of associations among variables in the analyses need to be evaluated in light of known risk factors to draw conclusions about likely explanations and plausible interpretations. In this case, uncontrolled confounding by socio-economic status appears to be the most likely explanation for the findings. This is due to the strong association between residential proximity to the river and socio-economic status.

The study's third objective was to compare the findings of this review to those of the earlier studies that prompted this investigation. Because of the similarities in study design and statistical analysis, the prior study's findings can be compared with the findings of the multivariate regression analyses in the current study, using Table 1 and Tables 8a and 8b. The major difference between the studies is the composition of the comparison areas for the analyses. Because of this difference as well as other differences (Table 3) the studies are not entirely comparable.

Table 1 shows some findings from the prior studies. Comparison with Table 8a and 8b from this study shows that the CV hospitalization rate ratios estimated for living in block groups adjacent or near the river in the current study are substantially lower than the rate ratios for residence in ZIP codes adjacent to the Hudson River in the previously published studies. In most cases the current analyses show elevations below 10% in contrast to elevations of 20% to 39% in the prior studies. The results of the current study are quite similar to the prior study results in terms of the associations reported for age, sex, race and income (Appendix B, Tables 1a and 1b) (Sergeev and Carpenter 2005, Tables 4 & 5, Shcherbatykh et al. 2005, Table 3) These similarities and the general methodological similarities between the current and prior studies suggest the likelihood that the prior studies' findings also were affected by confounding by socio-economic status. .

6. CONCLUSION AND RECOMMENDATIONS

While this type of study can neither prove nor disprove causal links among risk factors and health effects, it is useful for examining evidence for unusual patterns that might warrant additional investigation. This evaluation of hospitalization data, residential location and socio-economic factors in block groups in the 12 Counties abutting the Hudson River revealed a closely coinciding pattern of lower socio-economic status and residential proximity to the Hudson River, the proxy for potential exposure, and a strong association of lower socio-economic status and risk for CVD hospitalizations. The strong associations among residential location, socio-economic status, and CVD risk prevent us from drawing definitive conclusions from the multivariable regression analyses.

The multivariable analyses showed relatively small but statistically significant elevations of CVD hospitalization risk for residents of block groups in close proximity to the Hudson River. Stratified analyses conducted within each of the four income quartiles showed such elevations only among residents of lower income block groups. This study's data, methods and analyses can not provide a conclusive interpretation for this finding. However, the strong effect of socio-economic status on residential location (exposure proxy) and on CVD hospitalization risk makes it likely that the overall multivariable regression results are affected by uncontrolled confounding by socio-economic status.

To draw more definitive conclusions, particularly for outcomes such as CVD that are determined by multiple, known risk factors, studies seeking to investigate the role of PCB or POP exposures will require resource-intensive methods that include gathering individual-level exposure or biomonitoring information as well as individual-level medical histories and information on other risk factors.

This current investigation did not include environmental or biological sampling data. One study, described previously, did gather such data in the Hudson River region with the highest potential exposures (Hudson Falls/ Fort Edward). This study detected a statistically significant reduction in the total PCB concentrations in outdoor air samples at a distance of 1200 meters (3/4 mile) from the river. However, the PCB levels in outdoor air in this area were lower than those in other communities with known PCB-contaminated sites, and similar to levels reported in other locations in the northeastern United States. The study found no detectable differences in study subjects' serum PCB levels associated with proximity to contaminated portions of the river or other PCB sources. (Fitzgerald 2007, Palmer 2008).

It is recommended that the results of the current investigation of CVD hospitalizations and residence near the Hudson River be shared with NYS residents and other stakeholders with interest in this issue and be submitted for publication in a peer-reviewed journal.

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Table 1: Previous Study Results*: Statewide Analyses and Hudson River Specific Analyses**

Principal Diagnosis of Hospitalization	Adjusted Rate Ratio[a] (Lower 95%CI - Upper 95% CI)	
	NYS analysis	Hudson River Subset analysis
Ischemic Heart Disease[b]	1.15 (1.03-1.29)	1.36 (1.18-1.56)
Acute Myocardial Infarction	1.20 (1.03-1.39)	1.39 (1.18-1.63)
Cerebrovascular Disease[c]	1.15 (1.05-1.26)	1.20 (1.10-1.32)
Ischemic Stroke	1.17(1.04-1.39)	---
Hemorrhagic Stroke	1.10 (0.99-1.22)	---
Hypertension[c]	1.19 (1.08-1.31)	1.14 (1.05-1.23)

* Table adapted from Sergeev et al. 2005, Shcherbatykh et al. 2005 and Huang et al, 2006

** Ischemic heart disease and stroke hospitalization rates for NYS ZIP codes containing (or adjacent to) inactive hazardous waste sites with persistent organic pollutants compared to ZIP codes without (or not adjacent to) such sites

a. All analyses include a 2nd exposure category for other types of inactive hazardous waste sites and adjust for age, race and sex.

b. Ischemic heart disease analyses include all ages over 25. Ischemic heart disease analyses adjust for quartiles of median household income and health insurance coverage.

c. Cerebrovascular disease and hypertension analyses include ages 25-64.

Table 2: Comparison of Design & Methods for Previously Published Studies and Current Follow-up Study

OUTCOME ASSESSMENT		CONFOUNDER ASSESSMENT		EXPOSURE ASSESSMENT	
Previous Study	***Follow-up Study***	**Previous Study**	***Follow-up Study***	**Previous Study**	***Follow-up Study***
<u>Coronary Heart Disease</u>: 1993-2000 Ischemic heart disease (ICD-9: 410-414) and sequelae of myocardial infarction, not elsewhere classified (ICD-9: 429.7), Separate analysis of acute myocardial infarction (ICD-9: 410) Principal or other diagnoses (up to 14) combined **Reference**: Sergeev AV, Carpenter DO. Hospitalization rates for coronary heart disease in relation to residence near areas contaminated with persistent organic pollutants and other pollutants. Environ Health Perspect 2005; 113(6):756-761.	More years: 1990-2005 Same outcomes, with one addition, separate analysis of angina (ICD-9: 413). Only principal diagnoses. Use the admission source field to eliminate intrahospital transfers for the same individual	ZIP code level 4 levels of income – 2000 Census quartiles 6 age groups: age 25 and above 4 race groups: Asian/Pacific Islander, White, black, Native American.	*Block group level* *Same income categories* *Same age groups* *Different race categories: White, black, Asian/Pacific Island and Other, which includes Native American and Multiple Race* *Add education, population density, % hispanic and distance to nearest hospital as additional covariates.*	ZIP code level Exposure = residence within 196 ZIP codes with hazardous waste sites containing POPs or 222 ZIP codes with hazardous waste sites without POPs versus residence within 996 “clean” ZIP codes statewide **Sub-analyses (focus of follow-up):** Hudson River area: 78 POP ZIP codes versus 996 “clean” ZIP codes statewide	*Block group level* *Two types of exposure indicator categories within 12 counties abutting Hudson River:* ***Adjacency**: 255 block groups adjacent versus 2116 not adjacent to the Hudson River* ***Distance**: Block group population-weighted centroid distance from the Hudson River: <1/2 mile (225 block groups); between ½ and 1 mile (216 block groups); farther than 1 mile (1930 block groups).*
<u>Stroke</u>: 1993-2000 Cerebrovascular disease, excluding other ill-defined and late effects of cerebrovascular disease (ICD9: 430-436) Separate analyses of ischemic stroke (433.x1, 434.x1, 436) and hemorrhagic stroke (430-432) Principal or secondary diagnoses (up to 14) combined **Reference**: Shcherbatykh I, Huang X, Lessner L, Carpenter DO. Hazardous waste sites and stroke in New York State. Environ Health 2005; 4:18.	More years: 1990-2005 Same outcomes. Only principal diagnoses Use the admission source field to eliminate intrahospital transfers for the same individual	Restricted to 2^{nd} and 3^{rd} quartile income ZIP codes. 4 age groups: 25-64 2 race groups: White, black.	***(same as above)***	**(same as above)**	***(same as above)***

Table 3. Study Cardiovascular Disease Outcomes: ICD-9-CM Codes and Definitions

Ischemic Heart Disease:

ICD-9-CM: 410 - "Acute myocardial infarction (AMI)" is defined as a sudden insufficiency of blood supply to an area of the heart muscle, usually due to a coronary artery occlusion (obstruction), commonly known as heart attack.
ICD-9-CM: 411- "Other acute and subacute forms of ischemic heart disease" refers to complications or symptoms occurring before or after AMI, or a coronary artery occlusion (obstruction) interrupting blood flow to the heart, without AMI.
ICD-9-CM: 412 - "Old myocardial infarction" refers to a past AMI that is currently presenting no symptoms.
ICD-9-CM: 413 - "Angina pectoris" is defined as severe constricting pain in the chest, often radiating from the area immediately over the heart to the left shoulder and down the arm.
ICD-9-CM: 414 - "Other forms of chronic ischemic heart disease" includes coronary atherosclerosis, a chronic condition marked by thickening and loss of elasticity of the coronary artery caused by deposits of plaque.
ICD-9-CM: 429.7 - "Certain sequelae of myocardial infarction, not elsewhere classified," refers to other symptoms or complications associated with a prior AMI.

Cerebrovascular Disease:

ICD-9-CM: 430 - "Subarachnoid hemorrhage" is bleeding in the space between the brain and lining.
ICD-9-CM: 431 - "Intracerebral hemorrhage" is bleeding within the brain.
ICD-9-CM: 432 - "Other and unspecified intracranial hemorrhage" is bleeding, nontraumatic, between the skull and brain lining.
ICD-9-CM: 433 - "Occlusion and stenosis of precerebral arteries" is blockage or stricture of the arteries branching into the brain.
ICD-9-CM: 434 - "Occlusion of cerebral arteries" includes cerebral thrombosis and cerebral embolism
ICD-9-CM: 435 - "Transient cerebral ischemia" includes cerebrovascular insufficiency (acute) with transient neurological signs and symptoms
ICD-9-CM: 436 - "Acute, but ill-defined, cerebrovascular disease."

Table 4. – Census Demographics for Study Area by Proximity to the Hudson River: 2000

Census Demographics	Study Area		Within Block Groups Adjacent to River				Block Group Centroid Distance to River					
			Yes		No		< ½ mile		½-1 mile		> 1 mile	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Total Population and % distribution within river distance categories	2,924,631	100.0	315,662	10.8	2,608,969	89.2	231,414	7.9	283,321	9.7	2,409,896	82.4
Race/Ethnic Distribution		100.0		100.0		100.0		100.0		100.0		100.0
White	2,383,274	81.5	255,023	80.8	2,128,251	81.6	154,371	66.7	201,457	71.1	2,027,446	84.1
Black	277,302	9.5	34,039	10.8	243,263	9..3	43,895	19.0	38,959	13.8	194,448	8.1
Total "Other" *(listed below)*												
American Indian	*7,147*	*0.2*	*882*	*0.3*	*6,265*	*0.2*	*975*	*0.4*	*1,058*	*0.4*	*5,114*	*0.2*
Asian	*86,465*	*3.0*	*6,233*	*2.0*	*80,232*	*3.1*	*4,711*	*2.0*	*8,979*	*3.2*	*72,775*	*3.0*
Pacific Islander	*1,058*	*<0.1*	*111*	*<0.1*	*947*	*<0.1*	*104*	*<0.1*	*145*	*<0.1*	*809*	*<0.1*
Other	*105,182*	*3.6*	*12,492*	*4.0*	*92,690*	*3.6*	*19,288*	*8.3*	*23,338*	*8.2*	*62,556*	*2.6*
Multiple Races	*64,203*	*2.2*	*6,882*	*2.2*	*57,321*	*2.2*	*8,070*	*3.5*	*9,385*	*3.3*	*46,748*	*1.9*
Hispanic	268,036	9.2	28,449	9.0	239,587	9.2	40,691	17.6	46,978	16.6	180,367	7.5
Education												
<9th grade	108,312	5.6	13,370	6.4	94,942	5.5	13,585	9.1	14,518	8.1	80,209	5.0
9th-12th grade	200,374	10.3	27,023	13.0	173,351	10.0	23,306	15.5	25,161	14.0	151,907	9.4
High school or GED	519,236	26.7	62,727	30.2	456,509	26.3	44,366	29.6	51,585	28.7	423,285	26.3
Some college	336,283	17.3	36,464	17.5	299,819	17.3	24,995	16.7	31,141	17.3	280,147	17.4
Associates degree	150,134	7.7	16,574	8.0	133,560	7.7	10,134	6.8	12,939	7.2	127,061	7.9
Bachelors degree	342,297	17.6	28,578	13.7	313,719	18.1	18,898	12.6	24,584	13.7	298,815	18.5
Graduate or professional degree	285,823	14.7	23,199	11.2	262,624	15.1	14,813	9.9	19,909	11.1	251,101	15.6
+Other SES Factors												
Households below poverty	91,940	8.7	12,875	10.8	79,065	8.3	13,977	15.4	14,685	14.0	63,278	7.2
	mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Population density	5,746.6	9,589	5,449.6	11,391	5,782.6	9,346.8	13,501	16,071	11,068	16,248	4,376.3	6,690.9
Median household income	61,010	31,989	47,320	23,630	62,668	32,468	40,748	21,923	44,962	20,829	64,847	32,564

Sources: US Bureau of the Census. *2000 Census of population and housing summary file 1(SF1).* US Department of Commerce. 2001.
US Bureau of the Census. *2000 Census of population and housing summary file 3 (SF3).* US Department of Commerce. 2001.

Table 5. Study Population Person Years by River Proximity Category: For Income Quartiles and Race Categories

Person Years	Total	Adjacent	Non-Adjacent	<1/2 mile	½ to 1 mile	>1 mile
	n (row%) [column %]	n (row%) [column %]	n (%) [column %]	n (%) [column %]	n (%) [column %]	n (%) [column %]
Total Population	30,219,001 (100.0) [100.0]	3,269,547 (10.8) [100.0]	26,949,454 (89.2) [100.0]	2,380,477 (07.9) [100.0]	2,834,956 (09.4) [100.0]	25,003,568 (82.7) [100.0]
Income Quartile						
Lowest Income	7,182,853 (100.0) [23.7]	1,345,251 (18.7) [41.1]	5,837,601 (81.3) [21.7]	1,462,710 (20.4) [61.4]	1,236,936 (17.2) [43.6]	4,483,206 (62.4) [17.9]
2nd Income	7,778,921 (100.0) [25.7]	1,077,888 (13.9) [33.0]	6,701033 (86.1 [24.9]	420,361 (05.4) [17.7]	808,782 (10.4) [28.5]	6,549,777 (84.2) [26.2]
3rd Income	7,671,943 (100.0) [25.4]	551,617 (07.2) [16.9]	7,120,326 (92.8) [26.4]	344,840 (04.5) [14.5]	511,237 (06.7) [18.0]	6,815,866 (88.8) [27.3]
Highest Income	7,585,283 (100.0) [25.1]	294,790 (03.9) [09.0]	7,290,493 (96.1) [27.1]	152,565 (02.0) [06.4]	278,000 (03.7) [09.8]	7,154,718 (94.3) [28.6]
Race Category						
White	25,859,811 (100.0) [85.6]	2,784,914 (10.8) [85.1]	23,074,897 (89.2) [85.6]	1,761,910 (6.8) [74.0]	2,238,348 (8.7) [79.0]	21,859,554 (84.5) [87.4]
Black	2,466,185 (100.0 [8.2]	297,220 (12.1) [9.1]	2,168,965 (87.9) [8.1]	389,721 (15.8) [16.4]	316,704 (12.8) [11.2]	1,759,760 (71.4) [7.0]
Asian	792,737 (100.0) [2.6]	58,007 (7.3) [1.8]	734,731 (82.7) [2.7]	45,151 (5.7) [1.9]	78,161 (9.9) [2.8]	669,426 (84.4) [2.7]
Multiple, Other	1,100,269 (100.0) [3.6]	129,407 (11.8) [4.0]	970,862 (88.2) [3.6]	183,696 (16.7) [7.7]	201,743 (18.3) [7.1]	714,830 (65.0) [2.9]

Table 6. Study Hospitalization Record Exclusions

	Geocoded		After excluding continuation records		After excluding transfers		After imputing race & eliminating missing race*		After dropping poorly geocoded records		After dropping records with missing covariates (race,sex)	
	#	%	#	%	#	%	#	%	#	%	#	%
Total	202,272		201,814	0.2	169,143	16.2	167,733	0.8	154,236	8.0	154,220	0.01
(Loss %) Demographic group:												
White	155,216	84.9	154,805	84.9	132,749	85.9	144,262	86.0	132,343	85.8	132,332	85.8
Black	12,878	7.0	12,849	7.0	11,109	7.2	12,010	7.2	11,328	7.3	11,326	7.3
Other/Na	12,745	7.0	12,741	7.0	8,814	5.7	9,313	5.5	8,647	5.6	8,644	5.6
Asian/PI	2,021	1.1	2,020	1.1	1,810	1.2	2,148	1.3	1,918	1.2	1,918	1.2
Missing Race	19,412	9.6	19,399	9.6	14,661	8.7	(1,410)					
Diagnosis:												
IHD	137,569	68.0	137,303	68.0	111,005	65.6	110,005	65.6	110,000	65.6	101,012	65.5
AMI	51,840	25.6	51,635	25.6	39,338	23.3	39,338	23.3	39,013	23.3	35,811	23.2
Angina	5,792	2.9	5,788	2.9	5,316	3.1	5,316	3.1	5,285	3.1	4,731	3.1
Stroke	64,703	32.0	64,511	32.0	58,138	34.4	58,138	34.4	57,712	34.4	53,208	34.5
Isch str	23,673	11.7	23,543	11.7	21,012	12.4	21,012	12.4	20,912	12.5	19,371	12.6
Hem str	8,097	4.0	8,074	4.0	6,544	3.9	6,444	3.9	6,492	3.9	5,995	3.9

* Missing covariates: 11 records were missing sex, 325 were missing age, and 14,661 records were missing race. Race was imputed by random assignment based on block group of residence's race distribution for 13,251 records (310 were also missing other covariates. For approximately 1,100 records with missing race, geocoding was inadequate for assigning block group and 310 of those missing race were also missing additional covariates.). One discharge can have one or more covariates missing (i.e., missing covariates are not mutually exclusive.

Table 7. Income Quartile and Race Distributions for CVD Hospitalizations

	Study Population	IHD n=101,012	AMI n=35,811	Angina n=4,731	Stroke n=53,208	Ischemic Stroke n=19,371	Hemorrhagic Stroke n=5,995
Income (Quartiles)*							
Lowest Income	23.7	28.6	30.0	35.6	29.8	30.9	30.1
Second Income	25.7	25.4	26.5	23.7	25.6	25.6	25.2
Third Income	25.4	24.1	23.6	22.4	23.6	23.4	22.3
Highest Income	25.1	22.1	20.1	18.2	20.9	20.1	22.4
Total	100.0			99.9	99.9	100.0	100.0
White	85.5	85.9	88.5	83.3	85.8	84.4	80.9
Black	8.2	6.4	6.2	10.2	9.2	10.8	11.0
Asian	2.6	1.2	1.2	1.1	1.2	1.4	1.9
Other	3.6	6.5	4.1	5.3	3.8	3.4	6.2

* Study population income quartiles are based on census block median income. Quartile cut-points were developed by weighting block group median income levels by block group population to identify the cut-points within the continuous income distribution. After creating the cut-points, the study population of each block group was assigned to the appropriate quartile category. This resulted in the percentage of population in each quartile varying slightly from 25% because the entire populations of block groups were assigned to the same quartile.

Table 8a. Exposure Area Distributions and Rate Ratios for Ischemic Heart Disease Hospitalizations

Exposure	Person-Years (N=30,219,001) in	Ischemic Heart Disease Hospitalizations*					
		Total		AMI		Angina	
	No. (%)	No. (%)	RR (95% CI)	No. (%)	RR (95% CI)	No. (%)	RR (95% CI)
Adjusted for Age, Sex, Race**							
Adjacent Block Group							
Yes	3,269,547 (10.8)	12,327 (12.2)	**1.33 (1.12-1.57)**	4,398 (12.3)	**1.36 (1.14-1.63)**	591 (12.5)	**1.23 (1.06-1.42)**
No	26,949,454 (89.2)	88,611 (87.8)	1.00 Reference	31,380 (87.7)	1.00 Reference	4,137 (87.5)	1.00 Reference
Distance From River							
< ½ mile	2,380,477 (07.9)	9817 (9.7)	**1.20 (1.03-1.40)**	3,399 (09.5)	**1.26 (1.09-1.45)**	542 (11.5)	**1.60 (1.37-1.88)**
½ - 1 mile	2,834,956 (09.4)	11,236 (11.1)	**1.20 (1.04-1.40)**	4,048 (11.3)	**1.25 (1.09-1.44)**	610 (12.9)	**1.56 (1.33-1.83)**
>1 mile	25,003,569 (82.7)	79,885 (79.1)	1.00 Reference	28,331(79.2)	1.00 Reference	3,576 (75.6)	1.00 Reference
Add'l adjustment for SES and other factors***							
Adjacent Block Group							
Yes	3,269,547 (10.8)	12,327 (12.2)	**1.07 (1.04-1.11)**	4,398 (12.3)	**1.06 (1.01-1.10)**	591 (12.5)	1.06 (0.96-1.17)
No	26,949,454 (89.2)	88,611 (87.8)	1.00 Reference	31,380 (87.7)	1.00 Reference	4,137 (87.5)	1.00 Reference
Distance From River							
< ½ mile	2,380,477 (07.9)	9817 (9.7)	1.02 (0.98-1.06)	3,399 (09.5)	1.03 (0.98-1.09)	542 (11.5)	1.09 (0.98-1.21)
½ - 1 mile	2,834,956 (09.4)	11,236 (11.1)	1.03 (0.99-1.08)	4,048 (11.3)	**1.06 (1.01-1.11)**	610 (12.9)	**1.13 (1.02-1.25)**
> 1 mile	25,003,569 (82.7)	79,885 (79.1)	1.00 Reference	28,331(79.2)	1.00 Reference	3,576 (75.6)	1.00 Reference

*Age>25, 1990-2005, 50% sample.
**Adjusted for age (25-34, 35-44, 45-54, 55-64, 65-74, 75+ years), race (white, black, other), and sex (male, female).
***Adjusted for SES factors: quartiles of population density (6.1-506.6, 506.6<-2102.0, 2102.0<-6410.2, 6410.2<-94371.6 persons per square mile), median 1999 household income ($2499.00-40,968.00, $40968.00<-54650.00, $54650.00<-72944.00, $72944.00<-200001.00), % with less than a college education (0-30.6, 30.6<-42.7, 42.7<-55.5, 55.5<-100.0), % with Hispanic ethnicity (0-2.1, 2.1<-4.7, 4.7<- 9.6, 9.6<-86.0) and distance to nearest hospital.

Table 8b. Exposure Area Distributions and Rate Ratios for Stroke Hospitalizations, Age >= 25, 1990-2005

Exposure	Person-Years (N=30,219,001) in Study Area	Stroke Hospitalizations*					
		Total		Ischemic		Hemorrhagic	
	No. (%)	No. (%)	RR (95% CI)	No. (%)	RR (95% CI)	No. (%)	RR (95% CI)
Adjusted for Age, Sex, Race**							
Adjacent Block Group							
Yes	3,269,547 (10.8)	6,276 (11.8)	**1.25 (1.09-1.44)**	2,334 (12.1)	**1.28 (1.10-1.48)**	635 (10.8)	0.99 (0.86-1.13)
No	26,949,454 (89.2)	46,748 (88.2)	1.00 Reference	16,989 (87.9)	1.00 Reference	5,263 (89.2)	1.00 Reference
Distance From River							
< ½ mile	2,380,477 (07.9)	5,280 (09.9)	**1.16 (1.04-1.31)**	1,925 (10.0)	**1.20 (1.05-1.37)**	518 (08.8)	1.02 (0.88-1.17)
½ - 1 mile	2,834,956 (09.4)	6,023 (11.4)	**1.18 (1.06-1.32)**	2,227 (11.5)	**1.27 (1.12-1.45)**	658 (11.1)	**1.15 (1.00-1.31)**
>1 mile	25,003,569 (82.7)	41,721 (78.7)	1.00 Reference	15,171 (78.5)	1.00 Reference	4,722 (80.1)	1.00 Reference
Addl Adjustment for SES and Other Factors***							
Adjacent Block Group							
Yes	3,269,547 (10.8)	6,276 (11.8)	**1.07 (1.03-1.12)**	2,334 (12.1)	**1.10 (1.04-1.16)**	635 (10.8)	0.97 (0.88 – 1.06)
No	26,949,454 (89.2)	46,748 (88.2)	1.00 Reference	16,989 (87.9)	1.00 Reference	5,263 (89.2)	1.00 Reference
Distance From River							
< ½ mile	2,380,477 (07.9)	5,280 (09.9)	**1.06 (1.01-1.10)**	1,925 (10.0)	**1.08 (1.01-1.15)**	518 (08.8)	0.89 (0.81-0.99)
½ - 1 mile	2,834,956 (09.4)	6,023 (11.4)	**1.06 (1.02-1.11)**	2,227 (11.5)	**1.11 (1.04-1.17)**	658 (11.1)	1.08 (0.99-1.19)
> 1 mile	25,003,569 (82.7)	41,721 (78.7)	1.00 Reference	15,171 (78.5)	1.00 Reference	4,722 (80.1)	1.00 Reference

*Age > 25 years, 1990-2006,50% sample.
**Adjusted for age (25-34, 35-44, 45-54, 55-64, 65-74, 75+ years), race (white, black, other), and sex (male, female).
***Adjusted for SES factors: quartiles of population density (6.1-506.6, 506.6<-2102.0, 2102.0<-6410.2, 6410.2<-94371.6 persons per square mile), median 1999 household income ($2499.00-40,968.00, $40968.00<-54650.00, $54650.00<-72944.00, $72944.00<-200001.00), % with less than a college education (0-30.6, 30.6<-42.7, 42.7<-55.5, 55.5<-100.0), % with Hispanic ethnicity (0-2.1, 2.1<-4.7, 4.7<- 9.6, 9.6<-86.0) and distance to nearest hospital.

Table 9: Rate Ratios for CVD Hospitalizations Stratified by Income Quartile*

Rate Ratio for < ½ mile versus > 1 mile from river	**IHD**	**AMI**	**Angina**	**Stroke**	**Ischemic Stroke**	**Hemorrhagic Stroke**
	RR (95%CI)	**RR (95%CI)**	**RR (95%CI)**	**RR (95%CI)**	**RR (95%CI)**	**RR (95%CI)**
Adjusted for Age, Sex, Race**						
Lowest Income 1***	**1.23 (1.08-1.40)**	**1.24 (1.10-1.39)**	**1.39 (1.20-1.60)**	**1.20 (1.09-1.33)**	**1.22 (1.07-1.38)**	**1.18 (1.03-1.37)**
Income 2	**1.15 (1.01-1.31)**	**1.18 (1.01-1.39)**	**1.55 (1.24-1.95)**	**1.24 (1.13-1.35)**	**1.27 (1.09-1.47)**	---
Income 3	0.88 (0.75-1.03)	0.83 (0.68-1.02)	1.02 (0.76-1.37)	0.92 (0.79-1.07)	0.93 (0.76-1.13)	---
Highest Income 4	***0.80 (0.64-0.99)***	0.74 (0.54-1.03)	***0.30 (0.13-0.70)***	***0.78 (0.65-0.93)***	***0.71 (0.53-0.95)***	***0.43 (0.24-0.76)***
Weighted average:	1.00	0.98	0.91	1.02	1.00	0.71
Add'l Adjustment for other demographic factors****						
Lowest Income 1	**1.14 (1.07-1.20)**	**1.14 (1.06-1.23)**	1.12 (0.97-1.30)	**1.16 (1.09-1.24)**	**1.20 (1.10-1.31)**	1.09 (0.95-1.25)
Income 2	**1.10 (1.02-1.18)**	**1.11 (1.01-1.23)**	**1.36 (1.08-1.72)**	**1.10 (1.01-1.19)**	1.12 (0.99-1.28)	0.95 (0.76-1.19)
Income 3	***0.85 (0.77-0.94)***	***0.86 (0.75-0.97)***	0.93 (0.68-1.26)	0.97 (0.87-1.08)	0.96 (0.82-1.12)	***0.46 (0.33-0.66)***
Highest Income 4	***0.68 (0.60-0.78)***	***0.69 (0.57-0.85)***	***0.28 (0.12-0.62)***	***0.69 (0.59-0.81)***	***0.58 (0.44-0.77)***	---
Weighted average:	0.92	0.93	0.79	0.96	0.93	0.78

*To reduce the complexity of this Table, only one of the distance categories is provided. The other distance categories showed similar results.
**Adjusted for age (25-34, 35-44, 45-54, 55-64, 65-74, 75+ years), race (white, black, other), and sex (male, female).
***Block group median income quartile ranges: $2499.00-40,968.00, $40968.00<-54650.00, $54650.00<-72944.00, $72944.00<-200001.00.
****Adjusted for demographic factors: quartiles of population density (6.1-506.6, 506.6<-2102.0, 2102.0<-6410.2, 6410.2<-94371.6 persons per square mile), % with less than a college education (0-30.6, 30.6<-42.7, 42.7<-55.5, 55.5<-100.0), % with Hispanic ethnicity (0-2.1, 2.1<-4.7, 4.7<- 9.6, 9.6<-86.0) and distance to nearest hospital.

Table 10: Hospitalization Rate Estimates for Current Study and from Published Sources (age-adjusted to 2000 U.S. standard, per 10,000)

	Current Study, 12 Counties abutting Hudson River 1990-2005	Total U.S. CDC 2005*	Northeastern U.S. CDC 2005*	SPARCS NYS excluding NYC 2005-2007**
IHD	64.9	61.9	69.1	***
AMI	23.2	23.1	27.8	***
Angina	3.1	***	***	***
Stroke	34.9	30.3	30.7	35.1
Ischemic Stroke	12.7	***	***	***
Hemorrhagic Stroke	3.9	***	***	***

* Source: USDHHS 2005: National Hospital Discharge Survey, No. 385, July 12, 2007.
**Source: NYS DOH SPARCS 2009b.
***Comparable estimates were not able to be provided because published outcome groupings differed

Figure 1. ZIP codes by Adjacency to the Hudson River

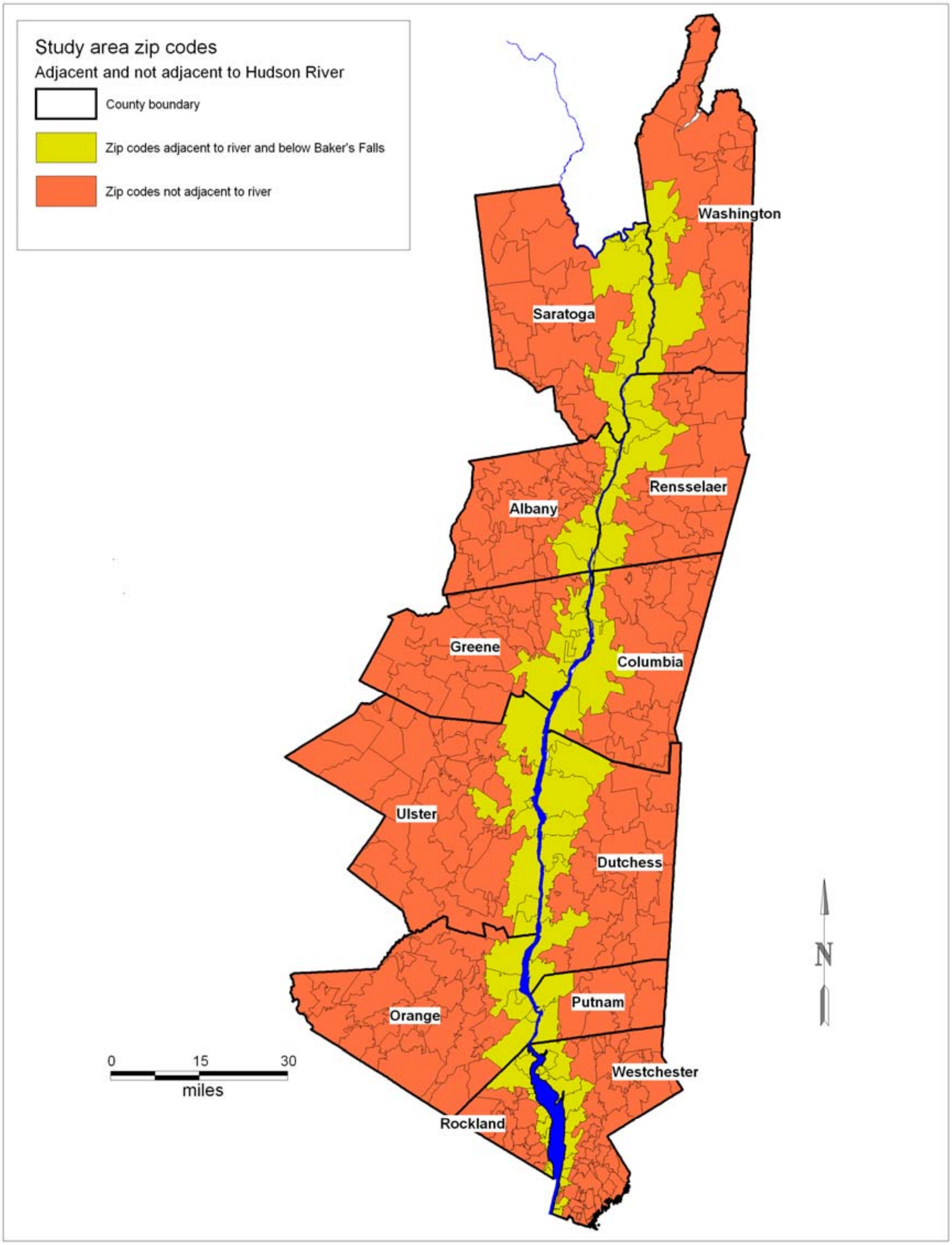


Figure 2. Census Block Groups by Adjacency to the Hudson River

Figure 3. Census Block Groups by Population-Weighted Centroid Distance to the Hudson River

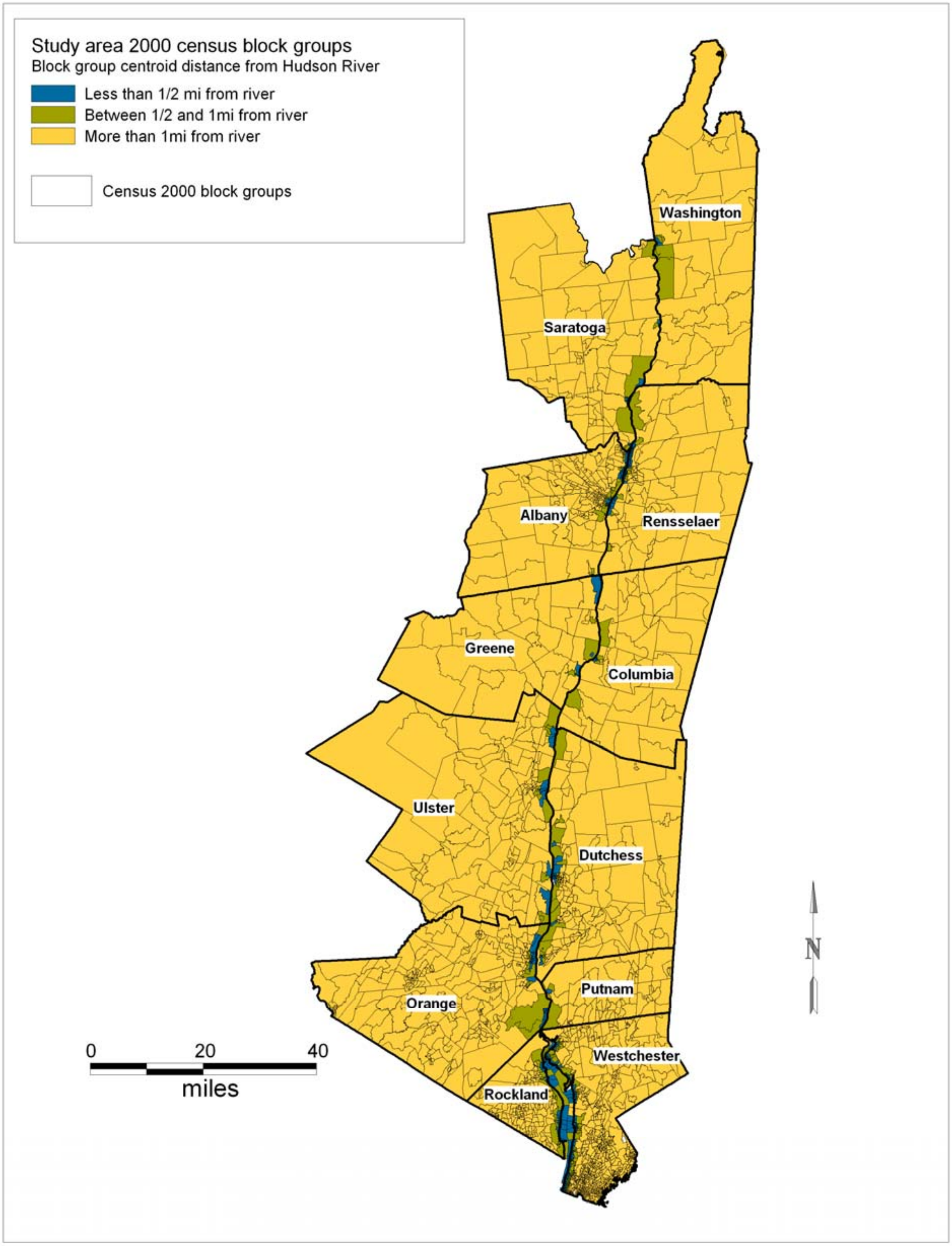


Figure 4

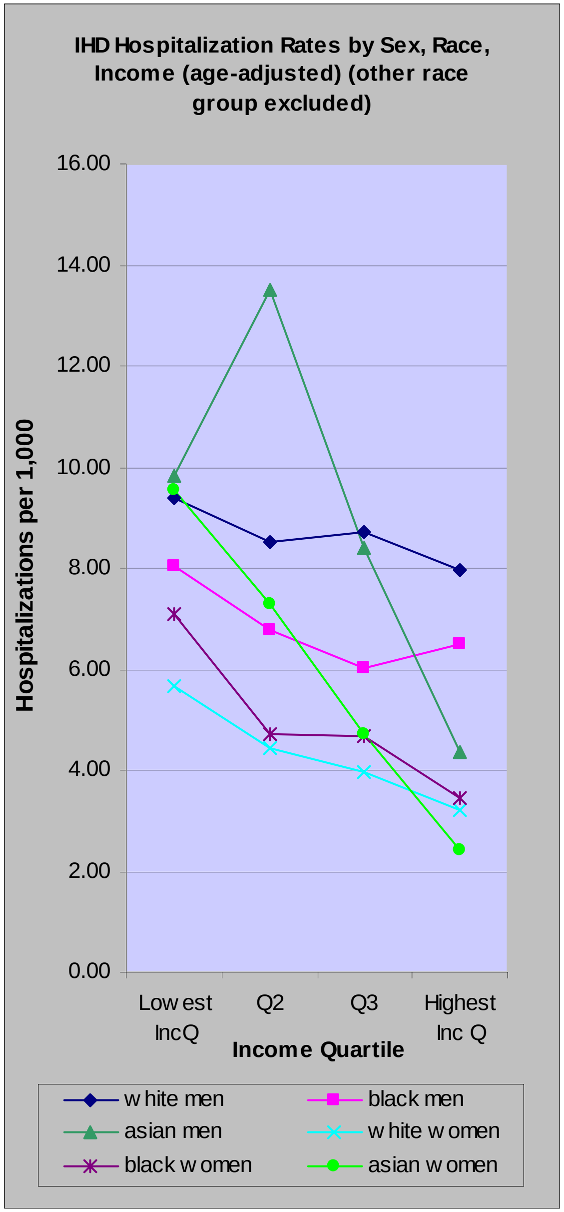


Figure 5

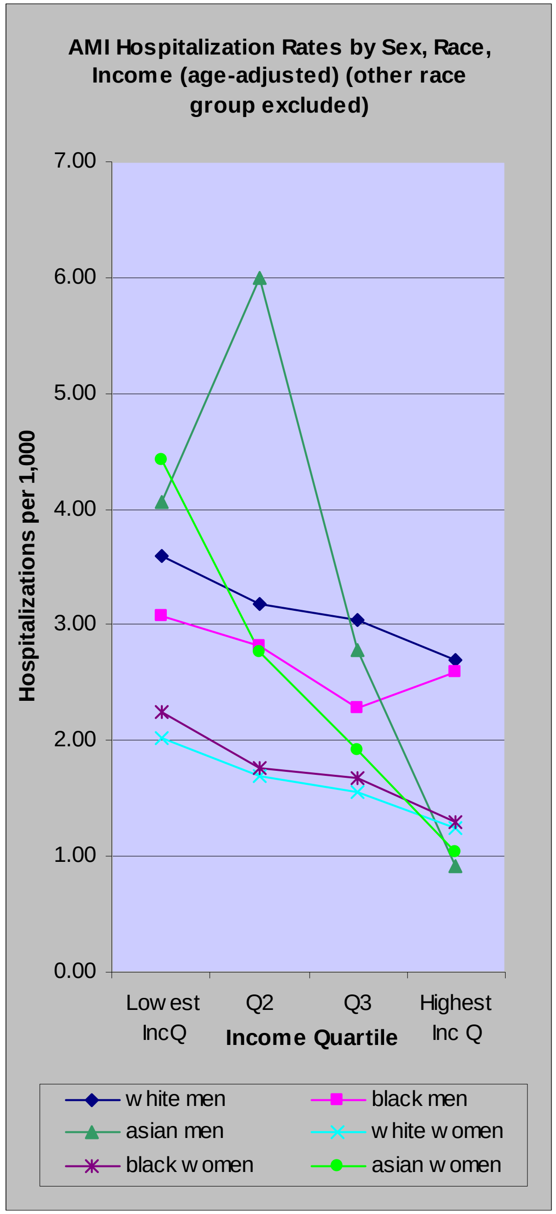
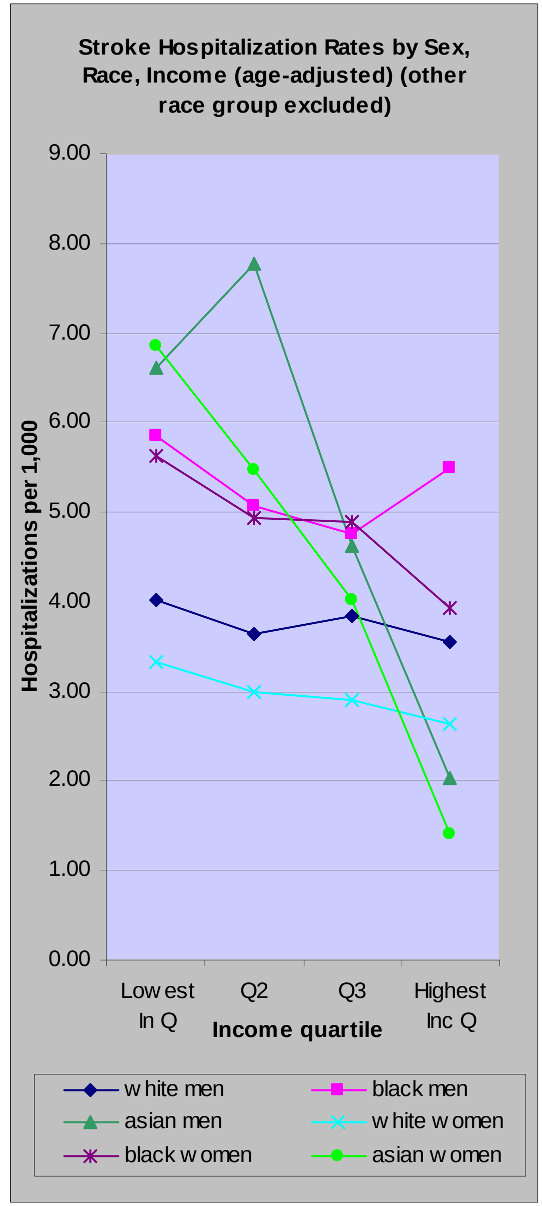


Figure 6



Appendix A: Representative Hinchey Letter

MAURICE D. HINCHEY
22ND DISTRICT, NEW YORK

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October 4, 2006

Howard Frumkin, M.D., Dr.P.H.
Director, Agency for Toxic Substances and
Disease Registry, and CDC's National
Center for Environmental Health
1600 Clifton Road, NE
MS E-28
Atlanta, GA 30333

Dear Dr. Frumkin:

First, I would like to congratulate you on your appointment as Director of ATSDR and CDC's National Center for Environmental Health. I look forward to the opportunity to work with you on important public health issues this year and in the future.

My second reason for writing today is to request that ATSDR assist my office in conducting a health consultation study for residents along a 200 mile segment of the Hudson River, a Superfund site on the National Priority List containing PCBs, in order to measure whether further evaluation may be warranted.

As you may know, Dr. David Carpenter has done a number of studies at SUNY Albany in New York that suggest that residency in proximity to hazardous waste sites with Persistant Organic Pollutants (POPs) may be associated with increased hospitalization rates for Coronary Heart Disease (CHD) when compared to hospitalization rates for areas with no waste sites or other types of waste not catagorized as POPs. I have enclosed a copy of three of these research papers that demonstrate this correlation for heart disease, hypertension and stroke.

I am very concerned about the health of the residents living along the Hudson River, and respectfully request that your agency look into what seems to be a very serious health threat. For purposes of my request, I would appreciate your agency looking into the subset population Dr. Carpenter examined in 78 zip codes along the 200 mile stretch of the Hudson River from Hudson Falls to New York City. This subset population studied by Dr. Carpenter showed a statistically significant increase in hospital discharges for heart disease, hypertension and stroke. Interestingly, according to CDC's data base, the Behavioral Risk Factor Surveillance System, this population on average has higher incomes, exercises more frequently and consumes more fruits and vegetables than the average New Yorker. Additionally, this population has more nonsmokers than the rest of Upstate New York's population.

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Since this type of population would typically exhibit better than average cardiac health, I'm sure you can understand and appreciate my concern and sense of urgency that we must follow up on Dr. Carpenter's good work and determine what further study is warranted to protect the health of the population living and working along the Hudson River.

I thank you for your kind attention to my request. I look forward to hearing back from you at your earliest convenience.

Best regards.

Sincerely,

Maurice Hinchey
Member of Congress

MH/ag

Appendix B: Table 1a: IHD Hospitalization Rate Ratios: age/sex/race adjusted versus additionally adjusted: For residents (age 25 and older) of block groups closer versus more distant from the Hudson River in models adjusting for sex, age, race, and block group median household income, population density, education level, percent Hispanic and block group centroid distance to nearest hospital: 1990-2005

		Adjusted Rate Ratios by Block Group River Proximity (95% Confidence Intervals)					
		IHD (N=101,012)		AMI (N=35,811)		Angina (N=4,731)	
Risk Factor		**Age/sex/race adjusted**	**Add'l adjustment**	**Age/sex/race adjusted**	**Add'l adjustment**	**Age/sex/race adjusted**	**Add'l adjustment**
Block group distance from River	< ½ mile vs > 1 mile	**1.20 (1.03-1.40)**	1.02 (0.98-1.06)	**1.26 (1.09-1.45)**	1.03 (0.98-1.09)	**1.60 (1.37-1.88)**	1.09 (0.98-1.21)
	½ - 1 mile vs > 1 mile	**1.20 (1.04-1.40)**	1.03 (0.99-1.07)	**1.25 (1.09-1.44)**	**1.06 (1.01-1.11)**	**1.56 (1.33-1.83)**	**1.13 (1.02-1.25)**
Sex	Male vs. female	**1.97 (1.74-2.23)**	**2.14 (2.08-2.20)**	**2.11 (1.87-2.38)**	**2.09 (2.02-2.15)**	**1.13 (0.99-1.29)**	**1.13 (1.06-1.21)**
Race	Black vs. white	**1.20 (1.02-1.42)**	**0.93 (0.89-0.97)**	1.09 (0.94-1.27)	**0.92 (0.87-0.97)**	**1.78 (1.52-2.08)**	**1.21 (1.08-1.36)**
	Asian/Pacific Is "	**0.80 (0.66-0.96)**	**0.73 (0.69-0.79)**	**0.85 (0.70-1.03)**	**0.72 (0.65-0.81)**	0.75 (0.55-1.02)	**0.65 (0.49-0.87)**
	Other "	**2.46 (2.08-2.91)**	**3.77 (3.63-3.92)**	**1.89 (1.62-2.20)**	**2.04 (1.91-2.18)**	**2.57 (2.15-3.07)**	**2.05 (1.77-2.38)**
Age	35-44 vs. 25-34	**8.09 (6.30-10.4)**	**8.24 (7.43-9.13)**	**6.47 (4.94-8.49)**	**6.58 (5.68-7.62)**	**4.91 (3.48-6.92)**	**4.98 (3.76-6.60)**
	45-54 "	**33.3 (26.1-42.6)**	**34.4 (31.2-38.0)**	**22.8 (17.5-29.6)**	**23.0 (20.0-26.5)**	**15.39 (11.08-21.4)**	**15.7 (12.0-20.6)**
	55-64 "	**82.7 (64.7-105.7)**	**80.2 (72.7-88.5)**	**57.6 (44.3-74.8)**	**51.6 (44.9-59.3)**	**27.8 (20.0-38.6)**	**28.4 (21.7-371)**
	65-74 "	**147.7 (115.5-189.0)**	**138.4 (125.5-152.7)**	**106.7 (82.0-138.7)**	**89.9 (78.2-103.3)**	**40.9 (29.4-56.7)**	**44.9 (34.4-58.6)**
	75+ "	**212.4 (165.6-272.4)**	**194.2 (176.0-214.2)**	**219.0 (168.3-284.9)**	**184.9 (161.0-212.3)**	**66.1 (47.6-91.9)**	**69.5 (53.3-90.5)**
Population density	2nd lowest vs least dense		**1.26 (1.21-1.32)**		**1.31 (1.24-1.37)**		**1.42 (1.27-1.59)**
	more dense "		**1.30 (1.24-1.36)**		**1.34 (1.27-1.41)**		**1.31 (1.16-1.47)**
	most dense "		**1.20 (1.14-1.26)**		**1.21 (1.14-1.29)**		1.15 (1.00-1.31)
Median Household Income	2nd highest vs highest income		**1.05 (1.01-1.10)**		**1.13 (1.08-1.19)**		**1.23 (1.10-1.37)**
	lower "		**1.09 (1.04-1.13)**		**1.23 (1.17-1.30)**		**1.25 (1.11-1.41)**
	lowest "		**1.16 (1.11-1.22)**		**1.29 (1.22-1.37)**		**1.62 (1.42-1.85)**
% with less than college	2nd lowest vs least college		**1.14 (1.09-1.18)**		**1.18 (1.13-1.24)**		**1.10 (0.98-1.22)**
	higher "		**1.22 (1.17-1.27)**		**1.26 (1.19-1.32)**		**1.15(1.02-1.29)**
	highest "		**1.22 (1.16-1.28)**		**1.28 (1.20-1.35)**		**1.29 (1.13-1.48)**
% Hispanic	2nd lowest vs least Hispanic		**0.93 (0.89-0.97)**		**0.94 (0890-0.98)**		1.01 (0.91-1.12)
	higher "		**0.92 (0.88-0.96)**		0.96 (0.92-1.01)		**1.18 (1.07-1.31)**
	highest "		**0.85 (0.81-0.88)**		**0.88 (0.84-0.93)**		**1.38 (1.23-1.54)**
Distance to Hospital	2nd closest vs closest		0.97 (0.94-1.00)		**0.94 (0.90-0.98)**		1.07 (0.98-1.18)
	more distant "		**0.90 (0.87-0.94)**		**0.93 (0.89-0.98)**		0.96 (0.86-1.07)
	furthest "		**0.87 (0.83-0.91)**		**0.91 (0.87-0.96)**		0.89 (0.79-1.01)

Appendix B: Table 1b: Stroke Hospitalization Rate Ratios: age/sex/race adjusted versus additionally adjusted: For residents (age 25 and older) of block groups closer versus more distant from the Hudson River in models adjusting for sex, age, race, and block group median household income, population density, education level, percent Hispanic and block group centroid distance to nearest hospital: 1990-2005

		Adjusted Rate Ratios by Block Group River Proximity (95% Confidence Intervals)					
		Total Stroke (N=53,208)		**Ischemic Stroke (N=19,371)**		**Hemorrhagic Stroke (N=5,995)**	
Risk Factor		**Age/sex/race adjusted**	**Add'l adjustment**	**Age/sex/race adjusted**	**Add'l adjustment**	**Age/sex/race adjusted**	**Add'l adjustment**
Block group distance from River	< ½ mile vs > 1 mile	**1.16 (1.04-1.31)**	**1.06 (1.01-1.10)**	**1.20 (1.05-1.37)**	**1.08 (1.01-1.15)**	1.02 (0.88-1.17)	0.89 (0.81-0.99)
	½ - 1 mile vs > 1 mile	**1.18 (1.06-1.32)**	**1.06 (1.02-1.11)**	**1.27 (1.12-1.45)**	**1.11 (1.04-1.17)**	**1.15 (1.00-1.31)**	1.08 (0.99-1.19)
Sex	Male vs. female	**1.14 (1.04-1.25)**	**1.27 (1.23-1.30)**	**1.26 (1.13-1.41)**	**1.31 (1.26-1.36)**	**1.14 (1.03-1.27)**	**1.23 (1.16-1.30)**
Race	Black vs. white	**1.94 (1.73-2.19)**	**1.53 (1.47-1.60)**	**2.33 (2.04-2.67)**	**1.91 (1.80-2.03)**	**2.15 (1.88-2.46)**	**1.90 (1.73-2.09)**
	Asian/Pacific Isl "	0.97 (0.83-1.13)	**0.88 (0.80-0.96)**	**1.14 (0.94-1.38)**	**1.01 (0.88-1.16)**	**1.42 (1.14-1.77)**	**1.29 (1.06-1.57)**
	Other "	**2.30 (2.03-2.60)**	**2.32 (2.19-2.45)**	**2.29 (1.97-2.65)**	**2.12 (1.93-2.32)**	**3.60 (3.10-4.17)**	**3.34 (2.96-3.77)**
Age	35-44 vs. 25-34	**3.09 (2.51-3.79)**	**3.03 (2.69-3.43)**	**3.59 (2.67-4.83)**	**3.62 (2.89-4.55)**	**2.74 (2.12-3.53)**	**2.68 (2.19-3.29)**
	45-54 "	**11.4 (9.38-13.9)**	**10.87 (9.70-12.17)**	**14.9 (11.3-19.7)**	**13.5 (10.9-16.7)**	**6.55 (5.13-8.36)**	**6.05 (5.00-7.34)**
	55-64 "	**33.1 (27.3-40.2)**	**32.9 (29.5-36.8)**	**43.3 (32.9-56.9)**	**41.8 (34.0-51.4)**	**11.9 (9.33-15.2)**	**10.9 (9.04-13.2)**
	65-74 "	**82.6 (68.2-100.1**	**86.1 (77.2-95.9)**	**114.5 (87.2-150.4)**	**111.4 (90.8-136.7)**	**21.4 (16.8-27.2)**	**22.4 (18.6-27.0)**
	75+ "	**189.0 (155.9-229.0)**	**203.7 (182.8-226.9)**	**276.8 (211.2-362.7)**	**306.0 (249.7-375.0)**	**55.4 (43.8-70.0)**	**58.7 (49.0-70.3)**
Population density	2nd lowest vs least dense		**1.26 (1.20-1.32)**		**1.24 (1.17-1.32)**		**1.29 (1.17-1.42)**
	more dense "		**1.26 (1.20-1.32)**		**1.21 (1.13-1.29)**		**1.42 (1.28-1.57)**
	most dense "		**1.24 (1.18-1.32)**		**1.28 (1.19-1.38)**		**1.50 (1.33-1.69)**
Median Household Income	2nd highest vs highest income		**1.06 (1.01-1.10)**		**1.10 (1.03-1.17)**		0.99 (0.90-1.08)
	lower "		**1.13 (1.08-1.18)**		**1.13 (1.06-1.21)**		1.07 (0.97-1.18)
	lowest "		**1.16 (1.10-1.22)**		**1.17 (1.08-1.26)**		**1.14 (1.02-1.27)**
% with less than college	2nd lowest vs least college		**1.11 (1.07-1.16)**		**1.12 (1.06-1.19)**		0.98 (0.90-1.07)
	higher "		**1.20 (1.14-1.25)**		**1.20 (1.13-1.28)**		1.02 (0.93-1.12)
	highest "		**1.16 (1.10-1.22)**		**1.19 (1.10-1.28)**		0.93 (0.90-1.08)
% Hispanic	2nd lowest vs least Hispanic		**0.96 (0.92-1.00)**		**0.94 (0.88-0.99)**		**0.84 (0.77-0.91)**
	higher "		1.01 (0.96-1.05)		0.96 (0.91-1.02)		**0.84 (0.77-0.91)**
	highest "		0.96 (0.92-1.00)		**0.88 (0.82-0.93)**		**0.78 (0.70-0.85)**
Distance to Hospital	2nd closest vs closest		**0.95 (0.91-0.98)**		**0.92 (0.87-0.97)**		0.97 (0.89-1.05)
	more distant "		**0.92 (0.88-0.96)**		**0.91 (0.86-0.97)**		**0.89 (0.81-0.97)**
	furthest "		**0.85 (0.81-0.90)**		**0.82 (0.77-0.88)**		**0.88 (0.79-0.98)**

Appendix B: Table 2: Sex and Race-Specific Age-Adjusted IHD, AMI and Stroke Rates by Income* (per 1,000)								
	Men				**Women**			
	white	**black**	**asian**	**other**	**white**	**black**	**asian**	**other**
IHD								
Lowest IncQ	4.70	4.01	4.92	9.40	2.83	3.54	4.77	5.43
Q2	4.25	3.39	6.75	14.43	2.21	2.36	3.64	6.90
Q3	4.36	3.01	4.20	24.63	1.99	2.33	2.36	9.02
Highest Inc Q	3.99	3.25	2.18	43.07	1.60	1.72	1.20	12.47
AMI								
Lowest IncQ	1.80	1.54	2.03	2.69	1.01	1.12	2.21	1.59
Q2	1.59	1.41	3.00	3.06	0.85	0.88	1.38	1.79
Q3	1.52	1.14	1.39	4.80	0.78	0.84	0.96	2.14
Highest Inc Q	1.35	1.30	0.46	8.20	0.62	0.65	0.52	2.75
Stroke								
Lowest IncQ	2.01	2.92	3.30	3.70	1.66	2.81	3.43	2.61
Q2	1.82	2.54	3.89	4.66	1.50	2.47	2.74	3.73
Q3	1.92	2.38	2.31	5.98	1.45	2.45	2.01	4.01
Highest Inc Q	1.77	2.75	1.02	9.05	1.32	1.97	0.70	7.76
* These rates are estimated from the 50% sample of hospitalizations in the 12-county study area included in this investigation. The rates are adjusted to the 2000 standard U.S. population								

CERTIFICATION

The health consultation for the ***Hudson River PCBs site, Residential Proximity to the Hudson River and Hospitalization Rates for Ischemic Heart Disease and Stroke: 1990-2005***, was prepared by the New York State Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner.

Gregory V. Ulirsch

Technical Project Officer, CAT, CAPEB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this public health assessment, and concurs with its findings.

Team Leader, CAT, CAPEB, DHAC, ATSDR