# Downwind, Downstream, Downtown: the Environmental Legacy in Baltimore and Montreal

By Olson, Sherry

ABSTRACT For two centuries, each surge of city-building has consumed massive amounts of raw materials and restructured flows of materials, as merchants and manufacturers reached out to capture resources from greater distances but persisted in accumulating a large share of the wastes close to home. Eight such surges of growth can be seen, and synchronized, in Baltimore, Maryland, and Montreal, Quebec. The environmental impacts are marshalled to appeal for more attention to material flows at scales that reflect the boom-and- bust context of urban decision making.

CHANGES IN THE METABOLISM of the city-the rate and efficiency with which it transforms energy-arise from changes of scale: the size of the population, the area it occupies, the resource areas it taps, and the sinks available for waste disposal.1 We experience such changes as everyday problems: smog, wheezes, overflowing drains, and overflowing dumps. Great efforts are underway to assemble global and national assessments of the balance of heat, nitrogen, or CO2, and, with a rising sense of urgency, citizens work at assessing their individual "footprints." As a complement to these metrics, I argue for more attention to material flows at the geographic scale of the metropolis and on a time scale cognizant of its boom-and-bust construction.

There are three reasons for considering the scale and tempo of urban growth. First, massive amounts of energy are baked into buildings and roads, or spent on transport of their materials. This energy is expended in great bursts, in a powerful rhythm known as the Kuznets cycle, with a period of fifteen to twenty-five years. The construction cycle is well documented for North American cities, but its effects have been neglected in both urban and environmental history.2 What we build in the span of four or five years creates a stream of future demands for operation and upkeep. Since the 1820s eight such surges have produced critical changes-of distances, densities, volumes, and surfaces-that modified the rates at which materials were subsequently required.

Second, the net direction of material flows in the North American economy is toward cities. Merchants and manufacturers repeatedly reached out to capture inputs from greater distances, but persisted in accumulating a large share of their wastes close to home. The pattern of flows that distinguishes a particular city today was modeled-and remodeled-in the creation of its infrastructure. Each surge of growth reengineered the hydrology and energy balance within the city, in the surrounding region, and at remote sites of exchange. We need to examine more systematically the effects of each surge of growth on habitats downtown, downstream, and downwind.

A third reason for disaggregating analysis to urban dimensions is political. It is at the scale of the polis that impacts of material f lows-the magnitudes and technological options, the economics, and the chemistry-can best be grasped without losing sight of the personal implications for city-dwellers: their health, life chances, range of choice, and sense of agency. Instrumental to each surge was a "growth machine" that enlisted builders, suppliers and shippers, lenders and speculators, property owners, and local governments dependent on property tax.3 A local growth machine was reassembled in each generation, and in the resistance or acquiescence that we observe in the municipal arena, we can explore relations of power without losing sight of human faces.

To develop the argument for such a research agenda, I will draw examples from two cities, Baltimore, Maryland, and Montreal, Quebec. Why two? And why these two? Studying a single city prompts questions: Is this a local peculiarity? Is this city different from all the others? Without making any great claim for the comparative method, I allowed events in one city to throw up propositions for the way cities worked, and treated the other as a test: Did it exhibit the same behavior and timing? I chose two cities where I have lived for a long time and explored the historical sources, where I have listened and voted.

Despite the personal bias of the starting point, the two cities offer a reasonable comparison for the purpose. For two centuries they ran neck and neck in population (Figure 1). Baltimore was incorporated in 1796, Montreal in 1840. Separated by six degrees of latitude, they differ greatly in climate and biological resources. Waves of migrants from different nations created a distinctive cultural mix, and the two populations, not being close neighbors, rarely paid much attention to each other. Yet they were embedded in the same way in the worldsystem: seaports at the head of navigation, more than 250 kilometers from the open ocean, and at roughly comparable distances from London and New York City.4 In both cities construction conformed to the same rhythm, as shown in Figure 2.5

In the first section of the essay, I will identify some trends of population and use of materials. Because of their common trajectory of growth, the two towns show numerous similarities, marshalled to show the extent to which their call on services of the natural capital of the earth was determined in the construction process. The second section is focussed on the points at which they took different paths. The relatively rare differences interject questions about the ecological context of the decisions, the cascade of consequences, and the exercise of power.

A COMMON TRAJECTORY

WITH ADVANCED ECONOMIES and comparable rates of population growth, Montreal and Baltimore might be expected to have comparable demands for ecosystem services. That expectation underlies the method of footprint analysis, designed to estimate demands on "life- supporting natural capital": How much biologically productive land does a community require to support its consumption of renewable natural resources? The various services of the ecosystem-to grow food, generate power, furnish raw materials, and assimilate wastes- are made commensurable in terms of the area that would be required for photosynthesis to replace that energy.6 But calculation of the ecological footprint, now widely applied to cities, relies primarily on national data with some questionable assumptions about uniformity of consumption from place to place.7 Only a few studies have employed disaggregated data for urban areas; few report historical trends or consider the surges in the accumulation of materials.8 The crude parameters available suggest that the two cities expanded their footprints in parallel (Baltimore in the lead), with the same spurts of growth.

TRENDS IN CITY-BUILDING

NATIVE PEOPLES OF NORTH AMERICA cleared little of the forest from either the Montreal Plain or the watershed of Chesapeake Bay, but by the mid-eighteenth century, when the towns were fewer than ten thousand people, European settlers had made a substantial impact on the landscape by cultivation of wheat. Silt carried by increased runoff from plowed land favored development of the port at Baltimore over Joppatown, but at the price of constant dredging, and, in the 1840s, loss of topsoil was aggravated by deeper disturbance of the steel plow. Under a summer storm regime, each burst of construction converted more woodland for residential use. Sediment transport and remodeling of streams were intensified by mechanized site preparation for large-scale developments of the 1960s.9 At Montreal, the natural channel was deeper, more vigorous currents ran close to shore, and the chief impediment to navigation was more remote-the shallows in Lac SaintPierre, seventy-five kilometers downstream. But here, too, to deal with increased sedimentation, dredging of the channel began in the 1840s.

Perhaps in response to the long and severe winters, where householders paid more for firewood than for the rent of the dwelling, Montreal developed as a more compact city, in each cycle building at somewhat higher densities. The two cities moved in the same direction, however, with densities increasing to the 1890s and falling thereafter.10 The shift to lower-density development was coupled with investments in local transport: electric tramways (1892), heavier rails, wider streets, deeper roadbeds, and heavier (four-horse) vehicles. By 1900 shop workers at the Grand Trunk Railway, Montreal's largest employer, were making a much longer journey to work than in 1890.11 Lower-density development required more miles of street per person, more pipe and wire. In both cities, investments in the new suburban infrastructure were subsidized by residents of the older core, and in the long run imposed on all citizens a higher average cost for services like street cleaning and garbage removal.12

Contributing to the higher per capita demand for land were trends to smaller households (from a mean of five persons in the 1880s to half that today) and more generously designed housing layouts, aimed always at the high end of the market. Over the twenty years 1970- 1990, for example, the population of the Baltimore metropolitan area increased only 20 percent, but its appropriation of land increased 90 percent, or 60 percent per person. Houses were built with larger floor area and furnished with more equipment: by 1950, the great majority had a bathtub, indoor toilet, and washer or dryer.13 Those so-called durables had finite lives, and their replacement added to construction debris. After 1950, more semidurables were added, with even faster turnover: TV, dishwasher, sound system, and computer. Over the entire twentieth century, the numbers of automobiles grew faster than the population, and faster in Baltimore than in Montreal. They occupied a larger share of the land, and emissions contributed to global warming by inhibiting infrared radiation into space. Citizens early recognized a local warming: an inner city warmer than the surrounding countryside. Both processes reflected the rising input of fossil fuels.14 Because of the difference in latitude, seasonality of energy demand differed, but the two cities shifted simultaneously from coal to oil heat, and then to the all- electric home. Baltimore households understandably adopted air- conditioning a generation earlier: 14 percent in 1950, 88 percent by 1983; of Montreal households, 24 percent by 1997, 47 percent by 2005. Demand for cooling intensified the production of heat, so that in Baltimore the difference of temperature between inner city and suburbs was greater in summer. At the latitude of Montreal, where the solar cycle varied more over the year and night cooling was more rapid, space-heating contributed to a greater difference in winter. Reciprocal demands in the two cities made it advantageous to spread the load and share the infrastructure, so that system interconnection at high voltages (1927) led to consumption of more power in both places.15

Once a neighborhood was laid out in a particular configuration of streets, lots, and buildings, the arrangement called for a characteristic stock of vehicles and committed a future stream of ecosystem services.16 Despite the "urban-rural demarcation line" drawn in Baltimore County in 1967 and "agricultural zoning" introduced in Quebec in 1978, conversion for urban purposes continued; and the trend engaged in the 1890s has not yet been arrested. Canada and the United States had the fastest-growing footprints in the world, and at transportation hubs like Baltimore and Montreal, advantageous prices promoted higher consumption of both staples and luxuries.17 More lavish use of space in Baltimore and more rapid turnover of consumer goods were associated with higher rates of economic growth in the United States. The exception was the period 1897-1913, when the Canadian economy ran ahead, with spectacular growth focussed in Montreal.18

CITY-BUILDING: THE PULSE OF CAPITAL

THE SMOOTH TRENDS of Figure 1, based on population counts at ten- year intervals, are misleading. Annual tracking from building permits shows a growth curve more like a roller coaster (Figure 2). Each surge of investment was associated with a surge of moves: immigrants from the "Old World" and people moving in from farms. The same rhythm governed investment in infrastructure and industrial capacity; even churches and schools responded to variation in the ease of borrowing. On the upswing entrepreneurs packaged projects in larger lumps, set them on larger sites, and organized larger flows of materials. An understanding of environmental impact therefore calls for an accounting of materials: volumes, sources, transformations, exports, losses, and net balance. Economists have debated the causes of the cycle of construction, but have said little about the tightly matched cycles of deconstruction and discard.

Although wood, sand, and clay persist as large components of built capital, flows of water and air through the city are much larger, and we will say a little more about asphalt, concrete, lead, phosphorus, and iron, to point to ways in which a surge of construction, or the choice of a material, affected hydrologic and atmospheric cycles.19 Asphalt and tar, for example, contributed to lower reflectance and higher absorption of heat, a factor powerful in the generation of the urban heat island and local impact on the energy balance of the planet. In the 1860s, as a response to the risk of fire (one fifth of Montreal dwellings had burned in 1852), gravel and asphalt replaced shingles as the preferred roofing materials. The religious communities that had founded Montreal were removing their hospitals and convents from downtown, and their large gardens were replaced by six-story warehouses. Faster run-off produced steeper peaks of streamflow, aggravated by the greater volume of water conducted from outside the city and turned (sullied) into the streets, so that in the 1870s both cities were experiencing flash-floods and, piecemeal, adding or enlarging storm drains. In successive booms, the sheer expanse of new roofs and pavements intensified flood peaks by shedding water instead of allowing it to percolate into the soil.

In the 1890s asphalt and gravel won the preference for paving as well, and the popularity of concrete-the truly impervious material- increased with advances of steel reinforcement.20 The first generation of steel-frame and concrete skyscrapers was tested in the Great Fire that destroyed Baltimore's ninety-eight-acre downtown in 1904. (Montreal built its first skyscrapers in the late 1920s.) In both regions, the most spectacular "impermeabilization" occurred in the mid-1960s with construction of expressways. In the Baltimore region, enough cement was poured in a single year to fill the Inner Harbor. In Montreal, the extreme example was the 100,000-acre site expropriated in 1969 for an airport, designed as the world's largest, with storm run-off directed to four different rivers. The concrete infrastructure of the 1960s, now approaching the end of its life-cycle, presents a radical challenge in terms of disposal, replacement, and refinancing.21 The trend to hard surfaces continued; in the Baltimore metropolitan area, impervious cover increased 40 percent over the 1990s. Impervious materials now cover a third of urban land (in either city), in the suburban counties a tenth, the threshold at which hydrology and wildlife habitats are irreversibly transformed.22

Such massive flows of materials into city-building raise the question as to where they came from. To what extent were environmental impacts local or remote? Most of the bulky construction materials were dug out of nearby claybanks, limestone quarries, and sand and gravel pits. The asphalt, the gypsum (7 metric tons for a new house today), and the coal to bake the brick or cement came from farther away. The break-in-bulk locations of the two cities favored basic industries and processes requiring large inputs of fuel, with corresponding generation of CO , waste heat, and a wide range of "impurities" from refining sugar, processing guano and fertilizers, cracking petroleum, and smelting ores of iron, zinc, copper, and chrome.23 Per capita consumption of materials for North America is estimated to have increased fivefold over the twentieth century, and a disproportionate share was transformed in seaport cities like Baltimore and Montreal. Baltimore Harbor today is rimmed with ninety-five connections to pipelines of twelve- to twenty-inch diameter, for emptying tankers of molasses, oil, liquid latex, sulphuric acid, asphalt, and cement.

Over the long nineteenth century, a strong and steady decline of ocean freight rates held down prices of raw materials, extended the reach of the urban market, and expanded the city's ecological footprint. Falling freight rates made cost seem small, and reduced the pressure to conserve materials. The gap between ocean and overland rates-in a ratio of 1:16 in 1830,1:10 after 1895-provided a critical locational advantage for the two cities as advance ports for inland markets. Their investment strategies were virtually identical, as merchants pressed for public works that would improve access to both the hinterland and the world network of cities. In the canal-building surge of the 1820s, Baltimore wholesalers, bankers, and owners of the copper and chrome smelters mobilized public loans for the first railway in North America, and a second coalition was assembled in 1840 to push the railway across the Appalachians: "Death or Go-Ahead." The Montreal Board of Trade in the 1850s spearheaded a movement to deepen the channel (Figure 3), bridge the St. Lawrence, and ensure rail connections to ice-free ports.24 Only with respect to the water-level route do we see the two towns self-conscious about competing with each other. Each seemed fixated on a nearby rivalPhiladelphia, New York, or Toronto- but striving, generation after generation, toward the same objective: to accommodate the world's largest and fastest vessels. To move the greater volume of goods across the docks and through the town, each push involved extending the piers, enlarging the sorting yards, and widening downtown streets.25

THE FUNNEL

WHILE HIGH-VALUE RESOURCES like chrome and copper were drawn from ever greater distances by efficient and well-capitalized systems, the demand for cheap construction materials bit into local landscapes, and waste materials, depleted of value, were disposed of as cheaply as possible or allowed to escape over the embankment, into older parts of the city, or into the harbor. This is what Luck et al. describe as the urban funnel: the more intense demand for certain kinds of ecosystem services close to home.26

From the moment they were empowered, the two municipalities attempted to arrest some of the practices that fouled the nest. They began by ordering yearly chimney-sweeping, daily washdown of markets, removal of offal beyond the city limit, and spoiled cargo fifty meters beyond the line of the docks. With each spurt of growth, they were obliged to undertake packaging and bulk transport of another portion of the waste stream: nightsoil, garbage, clinkers, horse droppings, and dead dogs. Like other cities, they did it inefficiently, by contract (with a percentage for graft), alternating between burning and landfill, with occasional recourse to piggeries. Citizens fulminated in summertime when smells offended and death rates doubled, but parsimony prevailed for most of the year. One by one, the quarries and gravel pits were converted, legally or illegally, into dumps, and, as they were filled or protested, into parks. The distances for carting both building materials and waste materials lengthened accordingly. In the 1960s surge, "megadumps" were licensed, ringing both Montreal and Baltimore at distances of thirty to forty kilometers. Exclusive access to such a site created an opportunity to seize control of hauling and price-making. In the suburban counties surrounding Baltimore, outlays on solid waste removal now run higher than any budget item other than schools, and in both cities the same firm, BFI, occupies a dominant position in the waste disposal market.27 The same trend characterized industrial wastes: value-depleted materials were tipped over the fence, and, when protest grew louder, sent a little farther by erecting a taller stack or extending the pipe deeper into the harbor. Like highly specialized raw materials, highly specialized wastes eventually had to be packaged, stored, and shipped. Medical wastes, for example, are transported into Baltimore from the mid-Atlantic states, while low-level radioactive waste from Baltimore is trucked to South Carolina for burial. High-level radioactive waste from the nuclear power stations at Calvert Cliffs, Maryland, and Gentilly, Quebec, is elaborately packaged for transport, but, since no community is willing to receive such hazardous material, it continues to accumulate on the spot.28

Of the materials funnelled into Baltimore or Montreal, phosphorus and lead are among those with highest rates of local accumulation. The phosphorus cycle is closely geared to human population: an adult ingests and excretes about 0.9 kilograms a year. From a vast area of rural soils-the orange groves of Florida, the wheatfields of Kansas and Manitoba-phosphorus is taken up by plants (and animals), delivered to the city, eaten, and excreted. As much as 90 percent is intercepted by a sewage treatment plant, concentrated in its sludge, and spread on relatively small areas of farms, gardens, golf courses, or dumps in the metropolitan area. Meanwhile, to compensate for losses in rural areas, rock phosphate from Florida or North Africa is transported, transformed (much of it in Baltimore), and applied to farmland at about twice the rate it is taken up by crops. As shown for Swedish cities, about half the waste phosphorus (in all those forms) finds its way within a decade into surface waters as excess nutrients.29

Flows of lead to urban areas responded more directly to growth of industry, roughly parallel with emissions of CO2, of highest intensity in the coal era, 1870 to 1920.30 In a surge of construction more lead paint and lead pipe were produced, contaminating factory sites now abandoned and "orphaned." Lead poisoning was recognized in the 1920s as a frequent cause of neurological damage in children, and the social costs included educational retardation and behavioral problems like hyperactivity. In the 1920s and again in the 1960s, Baltimore doctors attributed the problem to careless mothering and lead paint peeling from old houses, while the impact of airborne lead from the gasoline additive tetraethyl lead remained politically subliminal. Its toxicity was promptly discovered in the factories where it was produced (1923), but phaseout was not ordered in the United States until 1972, fifty years after its introduction, whereupon the manufacturer substituted a manganese "anti-knock" compound whose toxic effects are now demonstrated in Montreal.31

The heavy metals used in batteries, such as lead, manganese, nickel, and cadmium, contribute to electronic debris, already 5 percent of the waste stream. In Montreal, reprocessing of batteries at Nova Pb has in the last twenty years recovered 100,000 tons of lead, but 90 percent still ends up in landfills, or in dusts that are entrained and redeposited locally. Dust from the old gravel roads had long been a source of complaint, but the paved surfaces laid down in the 1920s and greatly extended in the 1960s yielded finer dusts, more insidious in penetrating the lung; and the wear and tear of rubber tires and brakepads released toxic compounds of copper, cadmium, lead, and zinc, borne by more efficient drains from the highways to the harbors.

DIFFERENCES

SO FAR, WE HAVE observed only modest differences. The same environmental innovations were introduced in the two cities within a year or two: manufacture of gas, municipalization of a water company (1846), introduction of horsecar service (1861), stringing of a fire- alarm telegraph (1876), electric tramways (1892), underground conduits for wires (1904), and chlorination of water (1910). Examination of patents awarded in the two cities shows that none of those innovations was founded on local invention; each town promptly adopted from others what seemed to be solutions to urgent problems they shared.32 Most of the changes required heavier public investment, greater inputs of fossil fuels, and a larger stream of industrial materials. In the 1890s, for example, as lower-density development was initiated; the municipal corporation dramatically expanded its capital budget, and the purchases of cast iron, lead, rubber, asphalt, and asbestos offered greater scope for political "machines."

Despite the similarities, there were four crucial divergences between Montreal and Baltimore. We can identify the choice points and consider how the choices reshaped the urban funnel. The four options involved both private and public actors, with respect to the handling of sewage, mass transit, generation of electric power, and production of steel.

ECOLOGY MATTERS, HISTORY MATTERS

AFTER LONG AND ACRIMONIOUS debates in both cities, Baltimore began in 1911 to collect and treat its sewage. Adoption of secondary treatment by bacterial digestion and trickling filters was a genuine innovation, the first on this scale in North America.33 Montreal managed to postpone action on this front until the 1970s, thanks to the depth and swift current of the St. Lawrence River that bore most of the run-off, sediment, human wastes, and industrial contaminants out of the city. Baltimore was forced to action by the shallowness and tidal behavior of its Inner Harbor: the downstream sump was right downtown. By sinking a large sum of capital, the choice set the city on a new path that would narrow the options available ever after. This is an example of path-dependence, where "history matters."34 Initiation of centralized sewage treatment, by requiring a full topographical survey, engendered a creative municipal vision for enhancing the relief by a network of streamvalley parks, parkways, and viaducts to develop the territory annexed in 1918. The demands of a technically sophisticated plant supported local engineering talent, and Baltimore has remained at the forefront of treatment of liquid wastes. Effluent from the trickling filters was not entirely innocuous, to be sure, and today contributes one quarter of nitrogen overload in the Bay. Recognition of the nitrogen problem led (2005) to a new round of investment in a European technology known as enhanced nutrient removal. Montreal, meanwhile, reluctantly faced the problem it had denied for a century: a twenty- year program, $1.4 billion, for gravity-flow interceptors to collect sewage from the entire Island and pump it through a plant that still performs only primary treatment.

Path dependence can also be seen with respect to choices in transit and electricity. In 1952, under the impetus of a GM-led road lobby that affected a hundred other cities, both cities switched from electric trams to unpopular diesel buses.35 Montreal moved to substitute an electric underground system (opened 1966), while Baltimore postponed any investment in subway or light rail until the 1990s. The delay, by leaving the field entirely to the automobile, reinforced suburban development at densities that would subsequently undermine profitable operation of rapid transit and subvert adaptation of the regional economy to the constraints of a world beyond peak oil.

Hydroelectric power was introduced in both regions in the boom before World War I and expanded in the 1920s surge. Quebec companies vigorously pursued hydro, were "nationalized" as a provincial corporation (1962), and consolidated and expanded, while the Baltimore company remained a private enterprise, aligned with owners of coal mines and coal roads.36 In the late 1960s Baltimore Gas & Electric built a large, 1,829 megawatt nuclear power station at Calvert Cliffs, downstream of Baltimore, while Quebec citizens rejected nuclear power, shrinking a grandiose proposal to a small operation at Gentilly, about one third that size. Their choices were shaped by relative access to sources of water power and coal, and once again the initial choices set the two regions on separate courses. HydroQuebec advanced its engineering prowess for winter construction and highvoltage transmission, to harness falls at greater distances. Since 1981 its James Bay project has brought 5616 megawatts into service a thousand kilometers from the demand centered at Montreal. It exerted unprecedented impacts on northern hydrology and created a new model for governance of Native lands. The coal-fired plants at Baltimore, on sites that date from 1910, remain on the "dirty kilowatts" list for SO^sub 2^, CO2, mercury, and NO^sub x^. If pressed, Baltimore Gas & Electric contemplates replacing Appalachian coal with low-sulphur coal from South America. Instead of investing in a closed-cycle process such as would be required in a new plant, it purchased emission credits for SO and continued the practice of once-through cooling water, four hundred tons of water for every ton of coal. The nuclear plant at Calvert Cliffs is producing one quarter of metropolitan Baltimore's power, and the company is the first in the United States to renew a license, extending the operation for another twenty years. THE SCALE OF PRIVATE ENTERPRISE

THE EXERCISE OF DIFFERENT options raises questions: Who made the decisions? Were they made locally or beyond the reach of the city? In private or in public? All of the projects described above depended on enabling acts and substantial subsidy or privilege from state or province, and the higher level of government frequently countermanded municipal options. The next examples introduce private actors who governed material flows larger than those public agencies: a steel plant in Baltimore and a copper refinery in Montreal.

Montreal foundries and wire and nail factories have relied on imported pig iron, initially from the United States and later from Hamilton, Ontario. In contrast, the Sparrows Point plant, 16 kilometers from downtown Baltimore, riding the crest of successive waves of construction, expanded to "world-scale" and played a unique role in reshaping the urban funnel. Outside interests first developed the site in the 1887 boom, just beyond the city's power to tax and regulate. Drawing ore from Cuba, they destined the entire output for rails.37 In the boom of 1910, the world demand for naval armor plate stimulated addition of vanadium, chrome, and nickel to their steels, and the contracts of World War I stimulated further growth. In the 1920s surge, a new mill a thousand feet long supplied tinplate to can-makers and local canneries for packing oysters and tomatoes from the Bay region. The reach was extended by a contract with Dole, such that iron ore mined in Chile and tin from Singapore were hauled to Baltimore; the tin-coated steel sheet was shipped to Honolulu to make cans and pack pineapple for return to United States mainland markets.

Wartime contracts provided another boost, and by 1950 Sparrows Point was the largest steel plant in the world. The government channel, deepened to thirtyfive feet, gave access to the world's richest ore bodies, and the three-thousandacre tidewater site was infinitely malleable: just dig and dump. In the conventional footprint calculation, a resident of Baltimore uses the same average amount of steel as a resident of Montreal, but because Baltimore was producing 40 precent of the nation's steel, local production of CO was much greater than we would expect from a city of its size. The smokestack was raised to 240 feet. The company town was razed to install new blast furnaces that created a distinct heat island and added to temperature differentials across the city. When increased drawdown provoked intrusion of brackish water into the deep reservoirs of groundwater along the harbor, the company adopted a novel solution by taking half the effluent from the city's sewage treatment plant for quenching steel. The mill returned the water to the Bay, along with 600 tons/day of waste pickle liquor, containing sulphuric acid and iron sulphides sufficient to coat Bear Creek with iron precipitate, induce extreme acidity (pH 4), and kill the fish. In the mid-1970s it was reputed the most polluting steel plant in the nation: ammonia, cyanide, phenols from the coke ovens and benzol plant, zinc and cadmium from the wire and tinplate mills, and chromium compounds in the refractory brick. The EPA closed the coke ovens, but down to the millennium the company was able to obtain delays for meeting state standards for emissions of copper and mercury.38

The "outsider" steel company provides an example of the power conferred by scale of enterprise. So long as wastes could be dumped into nearby public spaces, the volume of contaminants swelled with each surge of investment. Montreal producers, too, shaped the urban funnel. In the 1920s Noranda opened an electrolytic copper refinery in Montreal (Canadian Copper Refinery), with a corporate partner next door (Canada Wire and Cable) to take the product. It was supplied from a mine and smelter 630 kilometers away, and, in the next surge, another mine, smelter, and company town 850 kilometers away. By the 1990s they were bringing copper from Chile, but still dumping the process chemicals and "impurities" onto the riverbank or into the river. The story differs from the Baltimore case, since Noranda was selected in 1988 as one of 106 large firms to participate in a "voluntary" program to reduce "priority pollutants" in the St. Lawrence. Over seven years the copper refinery reduced its toxic reportables by 96 percent. From the slimes left from purification of copper, it began recovering gold, silver, selenium, and platinum. A new production process eliminated nitrous oxide waste and use of sodium hypochlorite. Storm runoff from the site is now neutralized; arsenic compounds are transferred offsite to remove them from the urban sink, and SO is recovered from waste gases and marketed as sulphuric acid (600,000 tons/year). Tailings and baghouse dusts are returned to the smelter at Home, Ontario. The mine at Home is no longer active, but the smelter receives metallic wastes from California and Rhode Island as well as Montreal, shreds and roasts them to produce more anode copper, and, for the final stage of purification, ships them back to CCR-Montreal at the rate of seven hundred short tons a day. Successful adaptations took advantage of a city-building surge of demand, so that a closed- cycle process could be piggybacked on plant expansion.

The limited-liability corporation was a crucial substructure in the ecosystem, a thick-walled cell whose mission was growth, dependent on importing resources and exporting wastes across that membrane. Some of these cells grew faster than their municipal "hosts," and the growth cycle offered opportunities for outside interests to capture local firms. Baltimore, in a span of eighteen months (1898-1899), ceased to be a city of home-owned factories, and became a "branch plant town." The seven fertilizer companies were amalgamated, as were the fourteen can factories, and sixteen of the twenty breweries. The city lost control of its railways; the tobacco plant and cotton duck mills became monopolies, as did coastal shipping. The transformation was part of a nationwide surge of finance capital, with loans for the Boer War and the Spanish American War, and a division of assets like steel mills, pipelines, and railways between J. P. Morgan and John Rockefeller.39 In Montreal, a wave of mergers a decade later coincided with exceptional buoyancy of the Canadian economy and the city's greatest surge of growth: flourmills and elevators were merged, monopoly positions were secured in cement, paints, steel wheels and railway cars, rubber, explosives, and the steamship lines to carry them. The effect of the mergers was to transfer out of town the power to shape the urban funnel.

OVERFLOWS

HOMO SAPIENS, by repeated doubling of population and ingenious introduction of ever-larger volumes of an ever-wider array of materials, was pursuing an experiment, testing the point at which some component of the ecosystem would overload, at risk of a "crash" in some vital subsystem. Because the experiment advanced more rapidly in cities, a great variety of overloads appeared. In the 1850s, anoxic conditions and a "great stink" attracted attention to the Baltimore Harbor. In the boom of 1871 the fish "took three gulps and died"; when depression closed the sugar refinery in 1877, the fish came back. In 1918, Baltimore faced an invasion of rats; and, as wartime industries tapped deep layers of groundwater (six hundred feet), wells were contaminated by intrusion of brackish water: both problems recurred in World War II.

Many of the overloads were highly localized, like the acidity in Bear Creek or the seventy centimeters of black gelatinous sediments accumulated since 1911 in Back River, the estuary that received the effluent of the sewage treatment plant. Problems perceived as short- term or local were not recognized as signs of system perturbation. In Maryland it was the oyster, valued as a regional specialty and livelihood, that issued a "wake-up call." A single oyster filters sixty gallons a day, and a carpet of oysters ensured three-day filtration for the entire Bay, but the ecosystem service supplied by the oyster population was appreciated only in the 1970s, after its capacity had fallen to 1 percent.

The challenge was to recognize the interactive nature of the system. What was happening in the urban funnel? Disturbance had continued over a long period, with excess sediments and excess nutrients enriching the waters and increasing turbidity. Since European settlement, sedimentation rates had increased between two- and tenfold in various parts of the Bay, nitrogen loading increased sixfold. In the late 1970s, a catastrophic decline in submerged vegetation of the Bay resulted in loss of species that found food and shelter there. Light and oxygen were becoming too scarce for bottom-living species like oysters, and the shift from bottom vegetation to floating vegetation induced a "near crash" of the entire system. In the summer of 2003 a "dead zone" stretched 240 kilometers below Baltimore, making 40 percent of the waters uninhabitable for fish and crabs as well as oysters.40

In the St. Lawrence, the shallows of Lac Saint-Pierre also hosted a rich array of species. Here the majestic St. Lawrence deposited much of its load of sediments and pollutants, beyond the everyday notice of Montrealers. The effluent of their sewage treatment plant traveled this route, alongside the waters of the "Back River" (Riviere-des-Prairies), the Ottawa, and the Great Lakes, their separate streams distinguishable to 150 kilometers downstream of Montreal. In addition to the effects of silt, excess nutrients, and industrial toxics, the St. Lawrence is affected by two other features of its management in the interests of the urban economy. First, to increase a flow of commerce carried in larger vessels, the flow of water was concentrated into a single channel, unlike its original branching distribution. A controversial surcreusage (overdeepening) in 1998 removed from Lac Saint-Pierre a volume equivalent to all the earth moved for the entire Seaway in the decade of the 1950s. To maintain such an artificial channel, constant dredging is required, as in the Chesapeake. Lower water levels in recent years, more frequent droughts, and anticipation of further climate change all intensify the pressure of shipping interests for further dredging to maintain the depth of channel. Every centimeter gained imposes a further commitment to annual dredging in years to come. The second type of disturbance arises from use of the river for power. To meet year-round demand for electricity, the seasonal regime has been modified. Islands and shores no longer receive the same spring freshets or sediment accretion; the wake and wash of larger ships add to bank erosion, and habitats are no longer appropriate for spawning and nesting of certain species.41 Especially difficult to recognize were system interactions among compounds released from different sources.42 A quarter of the excess nitrogen in the Bay came, as we have just seen, from effluent of sewage treatment plants; and we now know that another quarter comes from nitrogen released into the air by automobiles and power plants. A current study in Baltimore is designed to distinguish small, freshly emitted particles from "aged" particles that have attracted water and sulfates as they were borne across the Appalachians. A distinctive profile of contaminants identifies their sources: cadmium from the municipal incinerator, mercury from a medical incinerator, selenium from the coal-fired plant, arsenic and titanium from the steel plant, and vanadium compounds from the facilities that collect tolls from thirty thousand diesel trucks a day. Like the waters in the St. Lawrence, the various aerosols of Baltimore do not mix immediately or completely, and can be evaluated in terms of their specific effects on lung tissues, immune systems, and hospital admissions.43 New pollutants, diffuse in excretion or discard, are also finding their way to Lac Saint-Pierre and the Chesapeake Bay: anti-microbial soaps, f lame-retardant brominates, and endocrine-disruptors such as birth control pills, hormones fed to dairy cows, human antibiotics and probiotics for broilers. Since neither American nor Canadian governments have adopted precautionary principles, new materials come into production, into consumption, and into the waste stream faster than they are appraised. The emergent problems, too, are legacies of urban growth, accelerated by the growthmaximizing producer cells.

There is little room here to expand on the impact of these environmental changes on health of the urban population. I have shown elsewhere, in studies of infant survival in the two cities, that local environmental impacts were gendered, racialized, and class-structured.44 Industrial workers were among the first to suffer from the particular hazards of asbestos, tetraethyl lead, selenium, and chromate, but the signals were not heeded until such materials escaped from the workplaces and percolated into soils and groundwater. Workers in the Baltimore chromate plant, for example, were, as early as 1827, experiencing perforated eardrum, ulcerated nasal septum, dermatitis, and conjunctivitis. In the expansion of World War II, 60 percent were reporting such symptoms within three months of hiring. Despite some dust control effected in a plant expansion of 1955, these problems persisted, and when the plant closed in 1985, distribution of dusts, mapped in relation to employment and medical histories of fourteen thousand former workers (1942-1974), confirmed the rates of lung cancer as a function of cumulative exposure. Jobs with higher exposure were disproportionately filled by nonwhites, and for the hexavalent form of chromate the evidence showed no "safe" threshold. Despite the Baltimore evidence, the United States standard was not tightened until 2006.45 The coupling of environmental degradation with environmental (in)justice is a problem beyond the scope of this essay, but it will need to be addressed in order to understand why the effects on health did not result in prompt feedback to the production system. Were the social costs of environmental overflows not perceived in ways that would produce a prompt response? Or did the urban political process operate to conceal damages and delay action?

CONCLUSION

EACH SURGE OF URBAN growth produced a corresponding leap in size and complexity of the urban funnel, and, despite higher engineering efficiencies, a greater accumulation downwind, downstream, and downtown. Each surge of citybuilding put in place a future stream of demands for ecosystem services, and, in parallel, streams of debt service, profits, and losses. As a research agenda, we need therefore to develop a more complete set of metrics and narratives to analyse urban environments in the time-frame of their boom-and- bust construction. This allows us to recognize surges of construction as surges of discard, and to acknowledge accumulation of materials as part of the process of capital accumulation.

Comparison of two port cities has provided some cues for dissecting nationspace into hubs of material flow, and periodizing environmental history to recognize the rhythm of city-building. The periodization applies to all North American cities, but it has two limitations that will require special attention. First, residential construction fell very low during the two world wars, while flows of fuels, metals, water, and waste chemicals increased, as accumulation was diverted to "the treadmill of destruction."46 A second feature, already receiving attention, is the transfer since the 1970s of waste-producing industries to more distant locations, less likely to excite the concern of citizens of Baltimore or Montreal.47 As the urban funnel is reshaped to reduce local impacts, will local resistance falter, allowing increased impacts at the scale of the planet?

The two cases discussed here suggest a turning-point about 1900 when cities adopted a new pattern for local consumption and at the same time lost a degree of control over the local pattern of production. For earlier surges, we need the careful quantification of accumulation applied by Tarr, Ayres, and Barles, and the kind of double-entry bookkeeping applied by Ayres and Simonis to chromium, or by Brunner and Baccini to lead.48 All of the bookkeeping exercises have been trammelled by protection of "trade secrets" by corporate "persons." At the scale of the city, however, untapped historical sources exist in the realm of industrial archaeology, court testimony, port statistics, waybills, car loadings, remediation orders, and wartime planning agencies, for documenting changes in the shape of the urban funnel and magnitudes of local accumulation.

Then we need to ask questions about motivation. With what logic does the morning paper deplore a larger-than-ever "dead area" in the Bay, and, on another page, applaud the year's record tonnage of oil, nitrates, sulfates, and phosphates arrived at the port? The cyclical nature of construction nurtured speculative opportunities that developed political momentum. Can we identify the decisive moments on the upswing when new living arrangements were offered, greenfield sites were captured, and investments were made in both producer capital and public infrastructure? What reactions occurred on the downswing, when corporations declared bankruptcy and governments opted for cost-cutting? How did resistance harden? At what point in the cycle was living memory invoked?49 After the painful depressions of 1837, 1873, 1893, and 1929, unions and workingclass neighborhoods, hungry for jobs, were prepared to treat growth as urgent, and to accept what was presented as "a choice between Death or Go-Ahead." The boom-and-bust alternation made possible the manufacture of consent.50

And how were the costs and benefits distributed between social classes? Between residents and outsiders? Between one generation and the next? In the last thirty years we have begun to reckon costs we did not anticipate for site remediation, plant closures, and damages to human health. In the customary law that long applied in Montreal, a widow and her children always had the option of refusing an estate "more onerous than profitable." We do not have that choice with respect to the legacy of lead, mercury, or asbestos-all the wastes percolating in dumps, tailings, and groundwater, or lodged already in our bones, fatty tissues, lungs, and brain cells. Continued growth, coupled with the debts incurred, intensifies pressure to continue developing greenfield sites, shipping wastes to more remote sinks in unregulated environments, and transferring the costs to a yet more distant future. In this process, not only does history matter, but history will matter more and more. Montreal and Baltimore, like most great cities of the world, are engaged in trying to reverse its course.

Sherry Olson, "Downwind, Downstream, Downtown: The Environmental Legacy in Baltimore and Montreal," Environmental History 12 (October 2007): 845-66.

NOTES

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46. Gregory Hook

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