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STATE OF MAINE, BUREAU OF GENERAL SERVICES, JUNIPER RIDGE LANDFILL EXPANSION City of Old Town, Town of Alton, Penobscot County, Maine #S-020700-WD-BI-N #L-024251-TG-C-N APPLICATION FOR MAINE HAZARDOUS WASTE, SEPTAGE AND SOLID WASTE MANAGEMENT ACT, and NATURAL RESOURCES PROTECTION ACT PERMITS and WATER QUALITY CERTIFICATION	) STEVE COGHLAN) EXPERT WITNESS FOR) EDWARD S. SPENCER) INTERVENOR))) PREFILED WRITTEN TESTIMONY) FOR BOARD OF ENVIRONMENTAL) PROTECTION PUBLIC HEARING) FILED JULY 29, 2016)

Witness credentials and scope of testimony

My name is Steve Coghlan, and my current position is Associate Professor of Freshwater Fisheries Ecology in the Department of Wildlife, Fisheries, and Conservation Biology at the University of Maine. I earned a BS and PhD in Environmental and Forest Biology from State University of New York College of Environmental Science and Forestry (Syracuse, NY) in 1998 and 2004, respectively, studying ecology and environmental sciences in general and fisheries and aquatic ecology in particular. My dissertation research focused on the juvenile ecology of Atlantic salmon and feasibility of their restoration in the Lake Ontario watershed, and my teaching responsibilities included fisheries biology, aquatic entomology, ichthyology, and ecology of Adirondack ecosystems. I worked as an NSF-funded postdoctoral researcher and adjunct assistant professor at Arkansas State University (Jonesboro, AR) from 2004-2006, where I used biochemical analysis to study migration and life history in trout and aquatic insects. In 2006 I joined the faculty at UMaine with my responsibilities split between teaching undergraduate and graduate students and conducting fisheries research relevant to the State of Maine. Much of my current research focuses on ecological effects of dam removals in the Penobscot River watershed, especially in the context of restoring endangered, threatened, or declining fish species and the ecosystems that support them. I teach four courses to more than 200 students a year: Freshwater Fisheries Ecology and Management, Biophysical Economics, General Ecology, and Ecological Statistics. Out of a department of 7 teaching faculty, I am responsible for ~40% of credit-hours delivered to undergraduate students. I serve as Director of the Maine Chapter of the Center for the Advancement of the Steady State Economy (CASSE), and in my capacity as Network Speaker I give public presentations describing the science of how our human economy interacts with local ecosystems and the entire ecosphere, while providing visions of a sustainable society that lives within the limits of nature. I would consider my "areas of expertise" to be the realms of freshwater fisheries ecology and biophysical economics, but I am educated broadly in ecology and environmental sciences, and I am fortunate to learn a great deal from my collaboration with other UMaine faculty who are experts in fields such as wetland ecology, conservation biology, and population biology.

My written testimony submitted as part of the application process for the JRL expansion adopts a "systems ecology" perspective of how landfills (and the expansion thereof) relate to the interconnections among the human economy and the natural environment from which we humans derive our sustenance and wealth, including fisheries and their supporting watersheds. Part of my discussion focuses specifically on Atlantic salmon, an endangered fish species whose federally-designated Critical Habitat is located within the watershed impacted by this expansion. The rest of my discussion takes a larger view of waste production as a consequence of economic growth, in which our economy continues to enlarge the scope of human impact at the expense of all non-human life and our entire planetary life-support system. These considerations are all the more important given rapid, destabilizing climate change we're experiencing. I hope this avenue of discussion places the local issues surrounding one particular landfill, Juniper Ridge, in the context of issues facing our entire industrialized civilization on Planet Earth, in effect helping us to "think globally and act locally". Finally, wherever appropriate, I identify what I perceive to be shortcomings in the application regarding conclusions drawn from some mix of "objective science" and "subjective values". My testimony is based on my limited scientific understanding of natural processes that are governed and constrained by biophysical laws and principles, supported by empirical evidence whenever possible and consistent with theory when evidence is not yet available or impossible to obtain. I have tried to write my testimony for a broad audience of intelligent people, supporting my statements whenever possible with general and easily-obtainable references that themselves summarize or synthesize entire fields of research. I have avoided writing a highly-technical tome to a narrow audience of specialists in a particular scientific field, full of impenetrable jargon and bogged down with references to primary literature inaccessible to many in the general public. The purpose of this testimony is hopefully to enlighten and educate, not to obfuscate and distract.

Atlantic salmon: a fish of forests and wetlands, not of cities and landfills

Along North America's eastern seaboard, Atlantic salmon once ranged from Ungava Bay in northern Canada southwards to Long Island Sound and the Connecticut River. Today, they are on the brink of extinction in the US and, with very few exceptions, populations have declined throughout the rest of their range in Canada and Europe. Landlocked native populations in the Lake Ontario watershed were extirpated by 1898, and sea-run populations in the Long Island Sound DPS and Central New England DPS were extirpated in the 1800s. The Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic salmon, inhabiting 9 coastal watersheds, was listed as Federally Endangered in 2000, and the listing was revised in 2009 to include populations in portions of the Penobscot, Kennebec, and Androscoggin watersheds. Thus Maine harbors the last wild Atlantic salmon in the US, and the Penobscot River contains the largest river-specific population. Adult returns to freshwater streams have been too low to support sufficient natural reproduction for decades; number of spawners range from a few fish returning to the Denny's River to a few hundred in the Penobscot River. (See NOAA websites on Atlantic salmon for exhaustive literature review and supporting documents:
http://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/
http://www.nmfs.noaa.gov/pr/species/fish/atlantic-salmon.html)

Atlantic salmon have a long, complex life history that may encompass thousands of kilometers of geography. Spawning occurs in streams and small rivers; in the fall, adults dig nests in well-oxygenated gravel beds and bury eggs that overwinter protected from freezing, siltation, and predators. Fry emerge in the spring, disperse from nests, and defend territories in swift water from which they feed on drifting aquatic insects. Juveniles live in streams from 1 – 3 years, often moving extensively throughout a tributary system in search of high-quality habitat (cold water in forested landscapes). Once they reach a critical body size, they undergo a behavioral and physiological transformation called "smoltification" and prepare for a life at sea. As spring flows subside, smolts migrate downstream through the estuary and eventually out to the open ocean. Post-smolts may migrate as far north as Greenland where they feed for 1-2 years before returning to their home streams. Timing of transitions between habitats and life stages is critical, and is driven both by external factors (e.g., temperature, flow) and internal states (e.g., growth rate). Unlike Pacific salmon (*Onchorhynchus* spp.), Atlantic salmon are notgenetically programmed to die after spawning, and repeat spawners (especially females) are valuable because of their prior experience, large body size, and high fecundity. We could summarize this complicated sequence of events and critical habitats by stating a few basic needs: clean, cold water; free-flowing rivers; and a landscape containing intact, functioning forests and wetlands.

The reasons for the decline of Atlantic salmon, and many other sensitive fish species, are obvious and not surprising; they are entirely a consequence of the industrialized human economy and our relentless focus on increasing consumption, growth, and pollution (e.g., Limburg and Waldman 2009; Limburg et al., 2011). While salmon require cold, clean, free-flowing rivers embedded in a landscape of forests and wetlands, our industrialized economy heats and pollutes water, blocks rivers, and destroys forests and wetlands. Human activities that destroy Atlantic salmon and their rivers include pollution, deforestation, draining and filling wetlands, damming rivers, and overfishing; these impacts have been observed since medieval times, have increased in scope and magnitude with industrialization and European colonization of aboriginal lands, and have spread from Europe to eastern North America and now to Pacific salmon streams in western North America (Montgomery 2003). These disturbances often work in concert and are interactive – for example, deforestation might warm the river above the salmon's optimum temperature, causing increased metabolic energy expenditure and reduced energy available for growth, migration, and reproduction. Destroying a wetland and/or replacing it with impervious surfaces might increase runoff of nutrients and toxic chemicals into the river, which reduces dissolved oxygen and further compromises the salmon's metabolic performance. Dams block a salmon's ability to evade stressful conditions and access cold, clean water, and dams themselves may warm the water even further or facilitate the invasion of more tolerant fish species that compete with salmon. Overfishing removes the largest, most valuable females first and hastens population decline. Recent increases in temperature and extremes in precipitation from anthropogenic climate change (i.e., "global warming") likely will reduce or eliminate coldwater habitat in the southern part of the Atlantic salmon's range (e.g., Maine) and decrease habitat quality throughout much of the remaining range (Jonsson and Jonsson 2009). Of course, positive feedbacks exists between all the aforementioned factors and climate change – e.g., economic growth that destroys forests and wetlands promotes additional warming, which results in more greenhouse gas emissions, which increases warming further, and so on. All these risks decrease the likelihood of salmon surviving to maturity or gaining enough energy for successful reproduction. Based on my understanding and interpretation of decades to centuries of historical, biological, and ecological evidence, I think it is fair to state bluntly that a large and growing human economy, through its increasing consumption of natural resources, increasing production of waste, and increasing disruption of natural ecological processes, is incompatible with naturally-sustaining populations of Atlantic salmon. If we really were serious about conserving Atlantic salmon (and other endangered species), then first and foremost we would slow the growth of, and then decrease, the human footprint on nature and give non-human species and natural systems the "ecological breathing room" necessary to recover.

Will the Juniper Ridge Landfill Expansion impact Atlantic Salmon?

Language throughout the Application and supporting documents states confidently that we should not expect any negative impacts on Atlantic salmon, or a variety of other valuable species, habitats, and ecosystems. E.g., "this activity will not unreasonably harm any significant wildlife habitat, freshwater wetland plant habitat, threatened or endangered plant habitat, aquatic or adjacent upland habitat, travel corridor, freshwater, estuarine or marine fisheries or other aquatic life" (Volume V Page 8). Or, e.g., "These watersheds [containing Critical Habitat] will not be affected by the Expansion" (Volume V Page 53). In several cases, this conclusion is based on the premise that because Atlantic salmon don't live in the streams on JRL property, then they cannot be impacted – e.g., "A portion of the expansion area occurs within the broad area designated as Critical Habitat for Atlantic salmon (Salmo salar) listed under the Endangered Species Act (ESA), but the on-site wetlands do not contain any streams that would provide Atlantic salmon habitat" (Volume V page 262). Or, "Stantec also identified that the facility site falls within the mapped critical habitat for Atlantic salmon, which are protected under the final 2009 ruling issued by National Marine Fisheries Service (NMFS) and USFWS under the ESA. Specifically, the northeast portion of the facility site falls within the critical habitat for Atlantic salmon mapped by the National Oceanic Atmospheric Association. Stantec has evaluated the 780 acre parcel for natural resources in 2008, 2014 and in 2015. Although isolated forested wetlands occur within the facility site, and about two acres of these wetlands will be directly impacted by the expansion, there are no delineated or mapped streams in the 74-acre facility site, nor is the Expansion expected to result in impacts to mapped or delineated streams. Therefore, there are no expected impacts to Atlantic salmon or their critical habitat from the Expansion" (Vol I page 35).

Finally, in another instance, the language states conclusively that, "Based on review of the SWPPP prepared by the prior owner/operator of the JRL (Best Judgment, Criteria D of Addendum A of the MSGP), there is no reason to believe that there would be adverse impacts to endangered species due to stormwater discharge at the site. A Letter requesting a review and confirmation of no impacts on listed or eligible species or critical habitat was requested from the Maine Department of Inland Fisheries and Wildlife. A copy of the response is included in Attachment 12." (Volume 1 page

1453). Unfortunately, Attachment 12 (a letter from Assistant Regional WILDLIFE biologist Allen Starr) does NOT contain any sort of confirmation that Atlantic Salmon would not be affected, and does NOT even reference Atlantic Salmon.

I don't think that there's any way to draw such a conclusion about non-impact with such a high degree of confidence. Of course, any such conclusion drawn about an event that has not happened yet is tinged by subjective values and perception of risk. Certainly, if we could look into our crystal ball and guarantee that the landfill and its expanded area would NEVER leak, or storm runoff would NEVER reach the Penobscot River via Judkins Brook or Pushaw Stream, and that such water contained NO toxic chemicals harmful to Atlantic Salmon, then such statements are warranted. However, if our tolerance for risk to Atlantic salmon, an endangered species that has all but been eliminated in our state entirely by human impacts, was less and we wanted to err on the side of caution, we would not be so cavalier in drawing a conclusion of non-impact. What if there was a catastrophic breach of the containment liner from some low-probability event? What if there were an unprecedented storm event larger than the "once-in-25-years" or "once-in-100-years" considered in hydrologic simulations? (this is addressed below in discussion of climate change). What about effects on the rest of the Penobscot watershed, downstream of the landfill and the tributaries on JRL property, that do contain Atlantic Salmon? If we assume worst-case scenarios and an extremely unlikely but not impossible breaching or runoff event occurs, what sorts of toxins at what concentrations could we expect to drain into the Penobscot River? We already know that Atlantic salmon are extremely sensitive to, for example, various toxins in effluent from paper and pulp mills (such sludge is received by JRL; Volume Page 234); in fact, much of our knowledge of salmon physiology and metabolism comes from studies on salmon responses to paper and pulp effluent that provided the scientific rationale for the necessity of the Clean Water Act (Warren 1971). Much of the application for JRL Expansion focuses on the engineering details of the waste disposal and containment technology to assure us that these unlikely, catastrophic events won't occur, but I think we should be very cautious, and muster a healthy dose of skepticism, to rely on "advanced technology" to prevent or solve problems. I discuss technology further below, but suffice to say, human history is rife with example of technologies that don't live up to expectations, that fail (and spectacular technologies fail spectacularly!), and that actually cause worse problems than they solve (Huesemann and Huesemann 2011; Kunstler 2012).

In addition, there are two other Federally-listed fish species living in the lower Penobscot Watershed, downstream of JRL: Atlantic sturgeon (GOM DPS: threatened http://www.fisheries.noaa.gov/pr/species/fish/atlantic-sturgeon.html) and shortnose sturgeon (rangewide: endangered; http://www.fisheries.noaa.gov/pr/species/fish/shortnose-sturgeon.html). Even though their habitat does not extend upstream into watersheds on JRL property, shouldn't we consider downstream effects on their habitat? The letter from US Department of the Interior – US Fish and Wildlife Service (Volume 1, page 600) states that "Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species." I would argue that consideration of these 2 listed species should also be included in the Application. Also, the liquid leachate produced on JRL property and transported downstream to either Old Town or City of Brewer Wastewater Treatment Plants and discharged directly into the Penobscot River should be considered for all 3 of these federally-listed species, because the final discharge occurs in delineated or proposed Critical Habitat within the mainstem river. Volume 3 Page 55 states that "with the anticipated slight increase in leachate flows as a result of the Expansion (i.e., 48,000 average and 57,500 peak month) slightly more leachate will need to be hauled from the site. This increase represents about two to three additional trucks per day". The increase in average leachate hauled is 20% (48,000 compared to 40,000), which, to me, is more than slight. I suspect that this volume of leachate treated and discharged into the mainstem Penobscot River would alarm most reasonable citizens who value clean water, and there is no evidence in the Application that suggests such a volume is safe or prudent, other than it should conform to permitting regulations.

The First Law of Ecology: Everything is Connected to Everything Else

I believe that we should take a broader view of potential impacts that is more consistent with how individuals, populations, communities, economies, and ecosystems actually operate within a landscape. For a very long time, conservationists focused narrowly on single-species for restoration or rehabilitation efforts. For example, in response to declines of Atlantic salmon on the east coast and Pacific Salmon on the west coast, hatcheries were built to stock fry and smolts to compensate for losses of wild fish to pollution, dams, habitat loss, and overfishing (e.g., Saunders et al., 2006). Not surprisingly, without addressing the fundamental causes of decline, these efforts usually did not succeed; at best, hatcheries delayed total extinction in the short term, but at worst, masked the decline in wild fish from the general public's view while compromising the species' genetic variability with cookie-cutter fish ill-adapted to variable natural environments.

More recently, the Penobscot River Restoration Project (PRRP) is providing a world-class example of holistic river restoration that is founded on fundamental ecological principles (www.penobscotriver.org). The PRRP represents an unprecedented collaborative effort among local, state, federal, tribal, non-profit, and corporate entities that has tremendous grassroots support from local citizenry to heal past ecological wounds inflicted by our industrialized economy. First and foremost, the PRRP has improved access to thousands of kilometers of historic spawning and nursery habitat by removing 2 mainstem dams and improving fish passage at 2 other dams. Second, the PRRP has shifted focus from single-species (Atlantic salmon) to community- and ecosystem-level restoration. Under this paradigm, because Atlantic salmon co-evolved and co-existed for thousands of years with robust populations of other species like alewife, blueback herring, and sea lamprey, success of salmon is tied inextricably to success of those other species and restoration of their ecosystems. For example, upmigrating alewife are important because they act as "predation buffers" for downmigrating salmon smolts; predators on medium-sized silvery fish are much more likely to detect and eat one of millions of alewife swimming in large schools upstream while a few thousand smolts can swim downstream safely "under the cover of silver". In another example, spawning alewife and sea lamprey deliver huge quantities of marine-derived nutrients and energy to freshwater lakes and streams, thereby increasing productivity for juvenile salmon and entire ecosystems. So far, early results are promising; several sea-run species have increased in abundance, some by orders of magnitude, within the last few years, and these responses appear to be related directly to dam removal and improved quantity and quality of habitat (e.g., Hogg et al., 2013; Watson et al., 2015; www.penobscotriver.org).

I would argue that this proposed Expansion should be evaluated in the general context of ecological interconnectedness, and specifically in light of the Penobscot River Restoration Project. First, is it contrary to the stated goals and objectives of PRRP to expand JRL? Should we consider potential effects on alewife populations, who this year have returned to Pushaw Stream and Pushaw Lake in the tens of thousands (at least) to spawn, and likely will return in the millions? Should we consider potential effects on fish-eating birds drawn to the Penobscot by alewife and lamprey runs in close proximity to high-quality nesting habitat around the periphery of JRL property? Should we view the wetlands and vernal pools to be destroyed as parts of an interconnected watershed beginning to recover after centuries of overexploitation? Is it counterproductive to increase pollution load in one part of the watershed while we're trying to decrease pollution in much of the rest? I would argue that YES, digging a larger hole and dumping more trash in a landfill located in such close proximity to the Penobscot River, and also trucking and releasing more leachate downstream directly into the river, runs contrary to watershed-wide efforts to restore a river with a long history of misuse and abuse.

Looking ~~at the larger issue of landfills in general, I believe we need a different worldview to better understand how our economy and the waste it generates relates to nature, and how that relationship in turn feeds back to affect our society. Our conventional way of thinking (sometimes called "neoclassical economics" or NCE) is usually insufficient and often~~

wholly inadequate for identifying environmental problems and valuing non-human goods and services – that is, natural resources, pollution sinks, and ecological services (see reviews in Daly and Farley 2004; Hall and Klitgaard 2010; Czech 2013). A thorough critique of this economic worldview is beyond the scope of this brief testimony, but two major points are important and sufficient here: first, neoclassical theory and the models that guide our approach to identifying and addressing problems don't acknowledge the biophysical reality of nature, but rather view "the environment" as some abstract entity that provides "free and inexhaustible gifts"; basically, "the economy" is viewed as the entire, whole system that can grow without limits. A minor tweak to this worldview is of "environmental economics", in which the environment is located within (a subsystem of) the economy (the larger system). Essentially, the NCE view of the economy is that of a perpetual motion machine: it requires no energy or material inputs and produces no waste outputs (or, a bit more refined, that waste from one process can be used as a resource for another process). It can grow without limits and faces no external constraints. The astute reader will see that this view of the economy is equivalent to a car that runs ever faster on its own exhaust or an animal that grows ever larger by feeding on its own waste. A second point, either implicitly or explicitly part of NCE theory, is that "technology" is some magical phenomenon that arises from human ingenuity and creativity, provides only benefits while incurring no costs, and never fails. An alternative worldview, "biophysical economics" (or BPE) views economies as subsystems embedded within the environment; the economy exists as part of nature, not the other way around, and both form an interconnected system (Odum 1973; Hall and Klitgaard 2010). Economies transform energy and materials into goods and services, fulfill human needs and desires, and emit waste; nature is the source for the energy and materials and the sink for wastes. We can think of our economy as an industrialized metabolic system, much like we think of organisms and ecosystems as metabolic systems, who rely on a throughput of energy and materials to maintain themselves and grow. These metabolic processes are governed and constrained by biophysical laws and principles – most notably the laws of thermodynamics and entropy. Thus, BPE acknowledges there are limits to growth on our finite planet – the size and performance of our economy is constrained by the quantity and quality of resources available, the capacity of the ecosphere to assimilate our waste, and complex ecological interdependence (often viewed as "ecosystem services") that regulates climate, recycles nutrients, creates topsoil, drives evolution of biodiversity, etc.

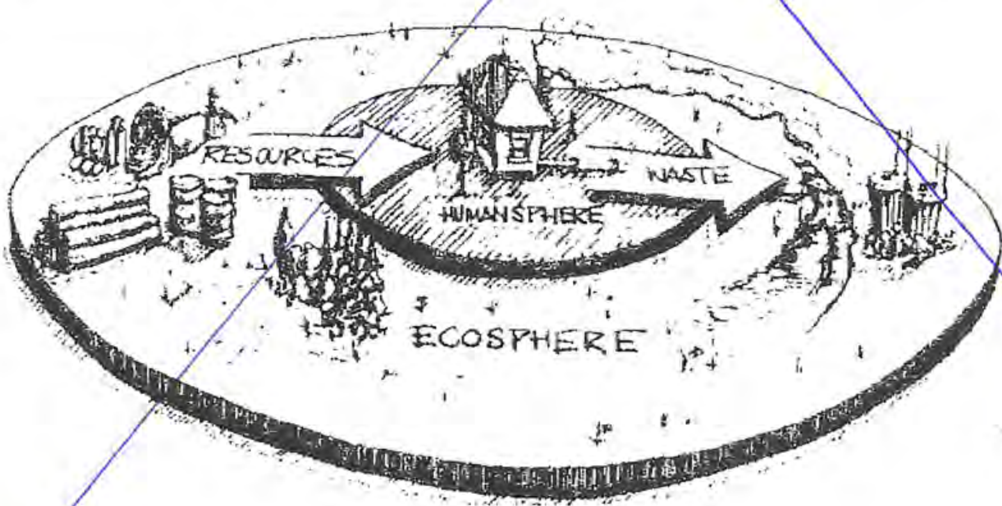

Figure 1. A simple drawing depicting the relation between our economy (the "humansphere") and our environment (the "ecosphere"; from Wackernagel and Rees (1996)

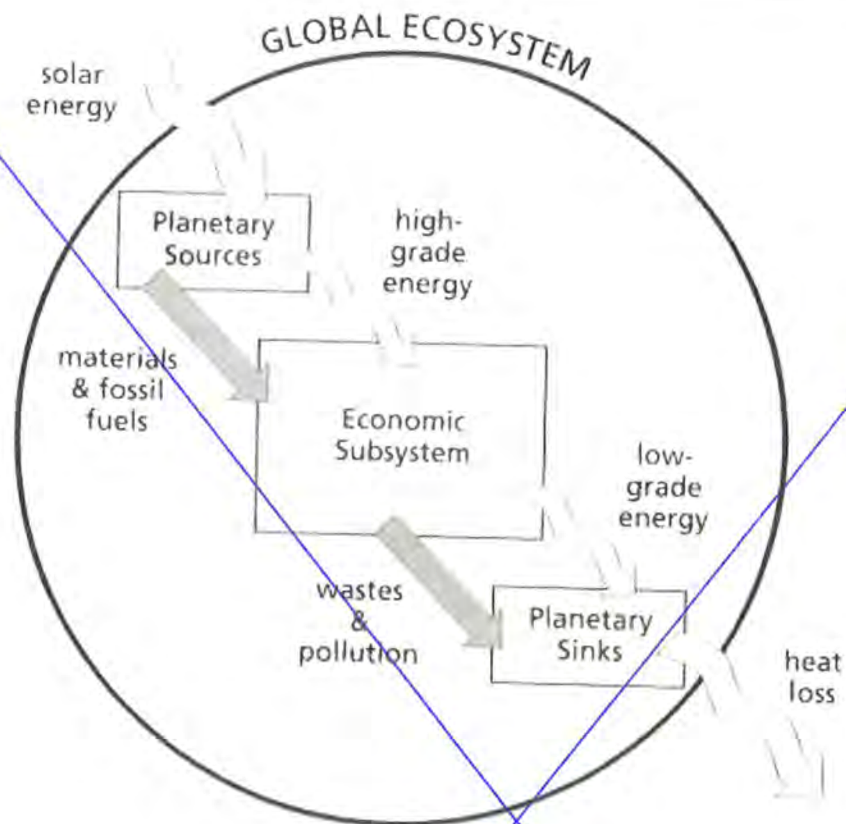

Figure 2. A slightly more detailed view of the relation between the economy and the ecosphere; from Meadows et al. (2004)

BPE was a natural outgrowth of the field of Systems Ecology that sought to quantify the connections among energy, economics, and the environment into one ecological system of interdependent actions (Odum 1973) Not coincidentally, the BPE view flourished in the early 1970s, at the dawn of ecological awareness and at same time as the US economy encountered its first serious limits imposed by energy shortages and pollution, during which conventional analysis from NCE failed miserably (e.g., Odum and Odum 2001; Hall and Klitgaard 2010). Important components of BPE and systems ecology were translated and popularized for the general public in the beginnings of the modern environmental movement by Barry Commoner's (1971) "Four Laws of Ecology": 1) Everything Is Connected to Everything Else – there is one ecosystem for all living organisms; what affects one affects all; 2) Everything Must Go Somewhere – there is no waste in nature and no "away" to which refuse can be thrown; 3) Nature Knows Best - humans have fashioned technology to improve upon nature, but such change in a natural system is usually detrimental; and 4) No Such Thing as a Free Lunch - exploitation of nature converts resources from useful to useless forms.

In the BPE view, technology is not magic, but a human contrivance that allows us to exploit nature more effectively, either by increasing flows of resources towards us and away from others (either away from non-human life, or away from other, unlucky humans who are too weak to resist, are in faraway lands out of our sight, or have not been born yet), or to project costs like pollution onto others (again, onto other living creatures or unlucky humans) (Catton, 1986;

Greer, 2015). Of course, technology follows biophysical laws such that there are limits to its effectiveness and scope, it comes with costs that often exceed benefits, and it fails - often spectacularly! (Huesemann and Huesemann 2011; Kunstler 2012). An economy run according to NCE principles with a relentless focus on creating new technology (which usually arise to combat problems caused by previous technologies!) for the sole purpose of growth is a gigantic "externalizing machine": it serves to maximize short-term gains that accrue to a few lucky participants by externalizing as many costs as possible to just about everyone else at the expense of long-term sustainability. In essence, our growth-obsessed, technocentric economy is designed to fail because it is driven to deplete its resource base and poison its environment as quickly as possible (Odum and Odum 2001; Meadows et al., 2004; Hall and Klitgaard 2010; Heinberg 2011; Kunstler 2012). The NCE model is incompatible with the biophysical reality of what is required for true sustainability of economies, societies, and our environment (Daly 1991; Costanza et al., 2014).

I would encourage Maine DEP and the Applicant for JRL expansion to consider very carefully who benefits from the expansion and who bears the costs. If the beneficiaries also bear the costs, we might consider the expansion in a different light than if all the benefits accrue to one group of participants but the costs are externalized on other groups that don't or can't share in the benefits. If the incentives surrounding expansion are such that large corporations benefit from decreased tipping fees and increased profits, or that far-away residents benefit from sending their garbage "somewhere else" cheaply, but the costs are borne primarily by local residents, future generations that have not yet been born but will be forced to deal with the consequences of a massive landfill that doesn't serve their needs, or by the non-human life and ecological systems in the surrounding landscape, then we cannot consider the expansion to meet conditions of equitability or sustainability.

If we choose to "think globally and act locally", we can see how landfills in general and expansion of JRL in particular relate to system-wide crises we're experiencing close to home and around the world. This is not an abstract thought experiment but an absolute necessity to respond intelligently to these problems - global warming, ocean acidification, water and soil pollution, biodiversity loss, fisheries collapse, peak oil, declining energy return on investment from fossil fuels, deforestation, wetland destruction, environmental racism, crushing poverty in the shadow of waste and opulence, financial instability, exploding debt and government bailouts, socioeconomic strife, political dysfunction - and many others. In essence, the BPE argument has been, more or less for 40+ years, that these crises arise as symptoms of an industrialized economy that has overshot the carrying capacity of our environment to provide resources and absorb wastes, and thus can no longer maintain growth, to provide all the necessities, luxuries, and standards of living demanded by a growing population (Odum and Odum 2001; Meadows et al. 2002; Hall and Klitgaard 2011; Heinberg 2010; Kuzyk 2014; Rees 2014).

In the early 1970s, systems scientists built the first computer models to investigate how the growing population and economy would interact with and respond to the limited carrying capacity of planet earth (Meadows et al. 1972,2004). They simulated several (up to 12) scenarios based on explicit assumptions about the size of various resource stocks and pollution sinks, allocation of industrial capital among various economic sectors, time lags between environmental signals and human responses, technology- and market-based solutions, and so forth. After 40 years of observational data to validate initial simulations, their "Business As Usual" scenario most closely matches our actual economic and ecological trajectory (Meadows et al. 2004; Turner 2008; Hall and Klitgaard 2010): specifically, we proceed along with no major policy changes and continue exponential growth in population size, economic throughput, resource consumption, and pollution. Growth eventually reaches limits imposed by the combination of filling of pollution sinks and declining quality of energy and materials as the best resources are exhausted. Growth in population and physical capital forces us to divert more capital, labor, and resources to cope with problems arising from this combination of constraints – most notably, pollution. Eventually so much capital is diverted to fighting overwhelming pollution and obtaining scarce, low-quality resources, it becomes impossible to sustain further growth in industrial output. When industry declines, society can't sustain growth in output of other sectors – food, human services, other discretionary consumption, etc. – and when those sectors stop growing, population growth ceases, birth rates decline and death rates increase, and various indicators of human welfare decline. The scenario is best described as "overshoot and collapse". Other similar BPE-based modeling scenarios draw similar conclusions, although their foci are more on limits to sources rather than limits to waste sinks (Odum and Odum 2001; Hall and Klitgaard 2010).

In the context of JRL expansion, we should take home 3 major points from these and other BPE-based studies: 1) our population and industrialized economy have already overshot planetary carrying capacity, perhaps by orders of magnitude (Catton 1986; Wackernagel and Rees 1996; Meadows et al. 2004); 2) we are producing waste faster than can be assimilated by the environment, and consuming resources faster than can be regenerated naturally, and thus our current economic trajectory cannot be sustained; and 3) the only way to reduce waste production to sustainable levels is to shrink our economy and its metabolic throughput to a size that is sustainable on a finite planet (Daly 1991; Callenbach 2014). This 3rd point is especially relevant to the State of Maine's Hierarchy of Waste Management: our first priority must be on waste reduction, and the most effective way to reduce waste from the tailpipe of our economy is to limit the resources (energy and materials) input as fuel; it is far less effective to manage waste already produced than to avoid producing it in the first place! (e.g., Daly 1991). This link between economic activity and waste production should come as no surprise, and even is acknowledged explicitly, albeit in an offhand way, in the Application: Volume I Page 337-338 states "Overall, Maine's waste generation has decreased, and thus the disposal capacity needs have decreased. However, if the economy improves in the near term, the department agrees with the applicant that waste generation is likely to increase". I assume that "improve" is used synonymously with "grow"; unfortunately, that conflation of "getting bigger" with "getting better" is all too common within the NCE mindset.

If we have already overshot carrying capacity, there really are only two options to reduce resource input, waste output, and hence the size of our economy: collapse uncontrollably on nature's terms, or manage a controlled degrowth and maintain a steady state economy of a sustainable size (Odum and Odum 2001; Meadows et al. 2004). It's questionable whether we have time, ecological breathing room, and the political will to enact a managed decline, but in my opinion, that's preferable to an uncontrolled collapse. Certainly, we can and should take action to reduce our ecological footprint and strive towards sustainability, and Maine DEP has at least started that conversation (http://www.maine.gov/dep/sustainability/index.html). However, the failure to acknowledge and adapt to biophysical limits to economic growth at all levels of society and government is, in my opinion, an inexcusable and impassable barrier to addressing the existential crises we face on our deteriorating planet. In my opinion, we have absolutely no hope of achieving sustainability in waste disposal or in any other societal endeavor, or in dealing with our existential planetary crises, until we adopt a BPE view of our interconnected economic-environmental systems, face the hard reality of constraints imposed by nature, and work within those constraints rather than deny their existence. I encourage Maine DEP and all partners in waste management to rise to that challenge.

The Elephant in the Landfill: Climate Change

A glaring and inexcusable omission throughout the entirety of the Application is the failure to acknowledge and consider anthropogenic climate change (ACC, or "global warming") specifically in performance of expanded JRL facilities and generally in longer-term waste management planning. The evidence is no longer deniable or ignorable: ACC has been occurring, we're seeing its effects here in Maine and around the world, and the pace is faster, and effects more serious, than earlier models suggested (Hansen et al., 2014, 2016). ACC is probably the most consequential hazard that human civilization has ever faced, and along with the interconnected constraints of declining societal energy return on investment and growth of unserviceable debt, threaten the existence of complex industrial societies on planet earth (Kunstler 2005; Heinberg 2010). ACC also represents a global externality of epic magnitude (Hansen et al., 2014) – the largest externalization of costs and internalization of benefits the world has ever seen. We have very little time, if any, to curb greenhouse gas emissions before we reach a tipping point into runaway climate change; some scientists think we have already passed the threshold of climate stability and resilience, beyond which self-reinforcing positive feedback loops take over and overwhelm stabilizing negative feedback loops and tip our climate into a state never experienced by the human species (Hansen et al., 2014, 2016). Obviously scientists can't predict with any certainty the DETAILS of future climate states, but they are confident in predicting the TRAJECTORY: overall, hotter with more variable / extreme precipitation (droughts alternating with floods) and more frequent / violent storms. We've already seen the probability distribution of temperatures shift significantly rightward, indicating that extremely hot years (say, 3 standard deviations greater than the historic mean) that were very rare in the past (<1%) are now occurring much more frequently today (~10%), and record high temperatures continue to be broken with regularity (for an excellent summary using the analogy of "loaded dice", see video interview with Dr. James Hansen: https://www.youtube.com/watch?v=TX2KyF0p-xU&feature=youtu.be). It's likely that we will also see a shift in the probability distribution of precipitation as more data become available, such that extremely heavy rains that once were rare events occur much more frequently now, and records continue to be broken by extreme events never before experienced in recorded history.

Any prediction of future landfill performance in withstanding extreme rainfall events and flooding should consider shifts in magnitude and frequency of storms and flood risks associated with a rapidly changing, unpredictable climate. However, this Application does NOT account for effects of ACC! For example, Volume I states that "As shown on the site surroundings map in Appendix M of this document, the Expansion is not located in a 100-year floodplain. As part of the design of the Expansion, post-development flow from a 25-year/24-hour storm event will be limited to pre-development levels. Appendix J of this document contains a Stormwater Management Plan for the Expansion, which describes the site setting, the pre- and postconstruction drainage plans and the stormwater structures design and routing that will limit postdevelopment runoff levels to predevelopment levels, demonstrating that this standard has been met." This type of conclusion drawn from simulation analysis is troubling because it is based on the assumption that future precipitation / runoff events and flood risks are the same as those experienced in the past, but all evidence suggests that the future is likely to be more extreme than the present. First, this map indicates the source of floodplain information was based on data from 1978, a full decade before Dr. James Hansen gave the first Congressional testimony indicating that he was able to detect the temperature signal of ACC through the noise of natural variability! Assessing the risk of flooding in the 2020s and beyond based on floodplains delineated from 40+ years earlier that have not been adjusted for ACC is misleading and dangerous. The map suggests that this historic floodplain nearly abuts the JRL property line towards the south, and is located within several hundred feet in many more places. Should we not anticipate the possibility that the likelihood of extreme flooding in the near future makes this floodplain delineation obsolete and the future floodplain may actually encroach upgradient and threaten the integrity of any containment structures nearby? ~~The same could be said for delineation of wetlands – if precipitation patterns change and flooding risk increases upgradient, might we expect new wetlands to form closer to the facilities?~~ Finally, if the frequency and magnitude of storms increase, shouldn't we anticipate for more extreme events with increasing frequency, such as what once would be considered 100-year or even 500-year storms? I believe that failure to account for changing patterns in precipitation and encroachment of floodplains consistent with ACC renders these simulations overly optimistic and underestimates the risk of a catastrophic breaching or runoff event.

ACC should also make us reassess the risk posed to all fisheries and wildlife habitat, including that for endangered Atlantic Salmon. As described previously, we should expect, for example, Atlantic Salmon individuals and populations to be less resilient and more susceptible to stressors under a warmer, more hydrologically variable climate regime. Fish may be able to withstand small amounts of watershed disturbance or toxic chemical runoff under optimal conditions of temperature and flow, but tolerance to these stressors would decline if other stressors, like high temperatures, already compromised metabolic performance. Similarly, a small amount of wetland destruction might not affect nutrient retention or flood mitigation if the entire surrounding landscape was intact and functioning optimally, but might be significant if integrity of the surrounding landscape was already compromised by ACC. Functioning wetlands, and especially forested wetlands like those on JRL property in Maine, are important carbon sinks and are critical to climate stabilization and mitigating effects of ACC; however, once disturbed and dessicated, these wetlands become a source of carbon to the atmosphere (Mitsch and Gosselink 2015; Dr. Aram Calhoun, Professor of Wetland Ecology, UMaine – personal communication). Because of the inherent non-linear responses and threshold effects exhibited by ecosystems to climate forcing, we can't be certain that a small disturbance simulated under past (stable) climate scenarios will yield a reliably small response under future ACC scenarios.

How shall we value wetlands?

Valuing natural resources (e.g., wetlands) and the ecosystem services they provide (e.g., nutrient retention and assimilation, biomass production, flood control, water filtration, wildlife habitat, etc.) with conventional NCE metrics is problematic for a variety of reasons. Howard T. Odum, the pre-eminent scientist usually considered the intellectual grandfather of both Systems Ecology and Biophysical Economics, worked with colleagues and students for 40+ years to identify these problems and develop alternative valuation methods; much of his work focused on wetlands (Odum 1995; also visit the University of Florida's Howard T. Odum's Center for Wetlands and his former student Mark Brown's Emergy Systems websites for vast repository of literature: http://cfw.essie.ufl.edu/ and http://www.cep.ees.ufl.edu/emergy/index.shtml). The most obvious shortcomings are that we don't pay nature for the economic work it does for free, and nature does not participate in market transactions. We pay money only to humans for the work they do in exploiting, transforming, and selling goods and services that ultimately originate from free natural resources and ecosystem services. Market valuation is based on what people are willing to pay, and is determined by the human receiver according to perceptions of short-range needs and expected benefits. Usually, these perceptions of value are clouded by poor or missing information. However, real biophysical wealth that is created by nature should be assigned a donor-determined value – that is, a measure of what was required to make the good or service measured in non-arbitrary units (compared to arbitrary units of currency that fluctuate widely in perceived value and purchasing power). We should be very careful not to confuse recipient and donor values! In fact, often times the two values are related inversely: when natural resources are abundant and contribute greatly to economic work, they are assigned a value because of their abundance and perceived non-importance; when natural resources are scarce and contribute less to economic work, they are assigned a high value because of their perceived scarcity. How then should we value nature more objectively and reliably than with a recipient-determined price?

Odum's answer was eMergy (notice the "M" rather than "n" as in "energy"). eMergy is a contraction for "embodied energy" or "energy memory", and can be defined as the total amount of energy of various forms transformed directly and indirectly throughout the entire production process to create a good or service, whether natural or man-made. The energy required for the transformations is no longer in the product or service, but energy carries the "memory" of the transformations, and flows of energy carry eMergy. Of course, although all different forms of energy can be expressed in their heat equivalents, they are NOT equivalent in their ability to do work. Therefore, different forms of energy are expressed according to their "transformity", which is defined as eMergy of one kind of energy required to generate a product or service of another kind. The more energy transformation steps there are, the higher the Transformity. eMergy is expressed relative to solar energy baseline, in units of solar eMcalories (shortened to "semcal"), and transformity is expressed as a ratio of seMcal / cal. For example, imagine a connected series of energy transformations in a hierarchy: say, sunlight → plants → coal → electricity, tracking the quantity of one kind required to produce the next. About 8,000 calories of sunlight is fixed into about 8 calories of plant biomass; 99.9% of the energy is degraded to waste heat following the 2nd law of thermodynamics. Of the 8 calories of plant biomass buried and subject to geological action, about 4 calories are transformed to coal; the remaining 50% is degraded into waste heat. Finally, burning 4 calories of coal in a power plant produces 1 calorie of electricity; the remaining 75% is degraded as waste heat. Thus 8,000 calories of sunlight is transformed into 1 calorie of electricity, with 7,999 calories lost to entropy. We could say that for this simple series of transformations, eMergy content of a 1 cal flow of electricity is 8,000 seMcal, and the transformity is 8,000. This shows that 1 cal sunlight is not equivalent to 1 cal electricity, even though the two values expressed in heat equivalents are the same. If we consider all the other inputs that are required to build the infrastructure of power plants, mine the coal, feed and clothe the workers, etc., we would find that transformity of electricity could be as high as 150,000! (Odum 1995). It should be clear that quantifying eMergy content and transformity captures the contributions of nature (and all other work) towards economic processes and evaluations, and thus is an objective measure of value.

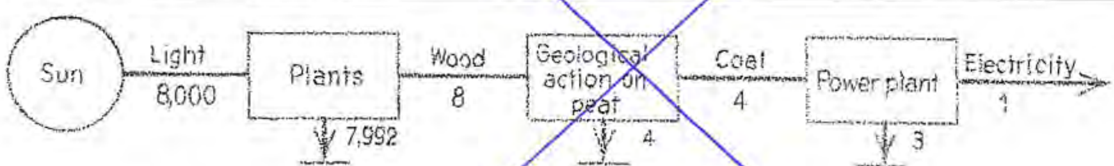

Figure 2-4 A scale of energy quality showing energy that must be degraded to upgrade each type of energy to the next level of quality.

Figure 3. A hierarchical diagram of energy transformations from low-quality sunlight to high-quality electricity, taken from Odum, H.T. and E.C. Odum. 1976. Energy Basis of Man and Nature. McGraw-Hill.

Not surprisingly, this method can be extended throughout the entire environment-economic system to account for the contributions of natural resources and free work provided by nature, plus human work, towards goods and services bought and sold in markets and other transactions. For example, combining information on the total eMergy flow through the system and the quantity of money exchanged via monetary transactions yields the metric of "eMdollars" – that is, the eMergy contribution that goes to support one dollar of gross economic product. Accounting for eMergy and eMdollars allows us to evaluate the "profitability" or relative costs/benefits of various economic decisions in terms of how real wealth is transacted among parties, and to estimate potential yields on various investments.

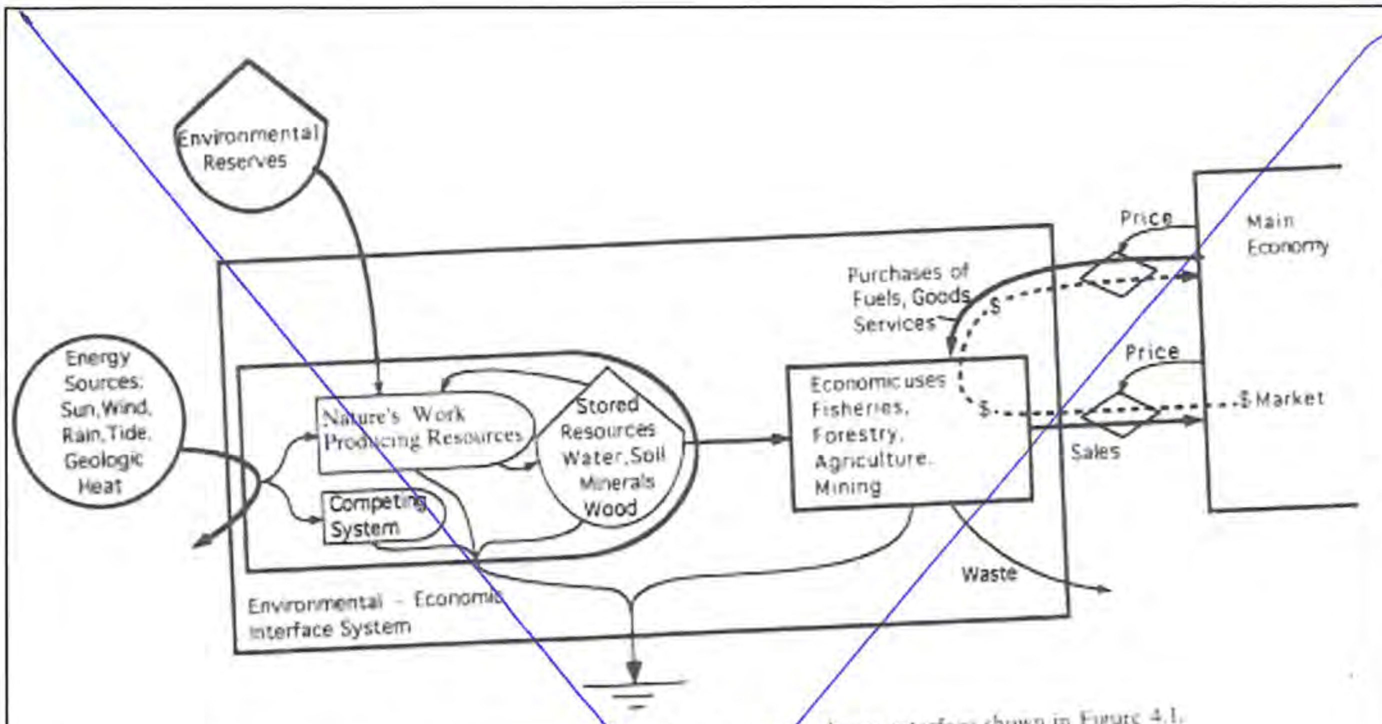

Figure 4.3. Enlarged window of the environmental production–economic use interface shown in Figure 4.1.

Figure 4. Systems-language model typical of that used in eMergy synthesis. From Odum 1995.

Many examples of using eMergy synthesis to value wetlands exist. In one case, Bardi (2002) concluded that wetlands are "extremely valuable"... and "provide between 2,295 and 6,430 em$/ha/yr of value to regional economies"; replacement values may exceed 1 million em$/ha. In another, Odum (1992) described a standardized procedure where one could estimate eMergy contributions coarsely, and thus value, of specific wetland types given some relatively easy-to-collect data. The point of calling attention to examples from this body of work is not to give an exhaustive review, nor to assert that the wetlands destined to be destroyed in the JRL expansion should be preserved because of high eMergetic value (to my knowledge, no estimates exist for these particular wetlands, but certainly could be made, given adequate research funding), nor to even suggest that wetlands might be valuable BECAUSE they can receive and process small amounts of stormwater (which is also evaluated with eMergy synthesis; Tilley and Brown 1998). Rather, the point is that eMergy synthesis is a well-developed, scientifically rigorous, and ostensibly objective valuation procedure, albeit one not considered in the Application. If the applicants were to conduct such a synthesis, we would have very useful information with which to value the impacted wetlands, and perhaps even to value the service provided by the landfill as well. As an aside, eMergy synthesis has also been used to evaluate the feasibility and profitability of recovering methane from landfills to generate electricity (Nepal and Campell 2012); I would encourage the Applicant to pursue this avenue as well.

One final point surrounding the idea of "wetland compensation". The Application describes compensation as "preservation of approximately 266 acres of the on-site parcel consisting of 57 acres of wetlands, 209 acres of adjacent upland, and 25 documented vernal pools". Although preserving this landscape certainly promotes the integrity and resilience of the Penobscot watershed, I don't agree that "compensation" = "preservation". How is not destroying a large part of the landscape equivalent to compensating for the destruction of a smaller part of the landscape? In my opinion, this is akin to a burglar compensating his victim by agreeing not to steal anything else.

Final Thoughts

Volume I page 31 states that "The Expansion has been located and designed to fit harmoniously into the natural environment." According to Dictionary.com, "harmonious" is defined as "forming a pleasingly consistent whole; congruous". Based on my scientific understanding of how nature functions and my personal relationship with the local area as a teacher, researcher, hunter, fisherman, forager, sustenance homesteader, and sustainability advocate, I see no way that JRL, expanded or not, could be considered as forming a pleasingly consistent or congruous whole with the natural landscape of forests, wetlands, and streams in the Penobscot River watershed.

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I affirm that this written pre-filed testimony is true and correct to the best of my knowledge and belief.

Steve Coghlan — 7/28/16

Signature — Date

Steve Coghlan

Expert Witness for Edward S. Spencer, Intervenor

1433 Southgate Rd. Argyle Township, ME 04468

stevecoghlan18@gmail.com

207-394-3899

Notary Public
Georgia Sharpe
term ending 9/11/22