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Transitioning to a new wastewater management paradigm: The potential for sustainable sanitation in Philadelphia

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Master of Science Thesis
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"*We are all downstream*."

Abstract

The current state of wastewater management in the city of Philadelphia is insufficient to meet the standards established in the U.S. *Clean Water Act*. This thesis investigates the problems facing wastewater management in the city by analyzing the institutions, stakeholders, and historical development of the current wastewater management system. Alternatives to the current centralized system, known as "sustainable sanitation", follow the spectrum from low-tech to high-tech, but are united by the fact that they address the three main problems plaguing contemporary centralized wastewater management systems: (1) closing the water cycle; (2) a shift away from the ideology of "waste management" to one of "resource recovery", specifically with respect to energy and nutrients; and (3) addressing the need for wastewater treatment at a decentralized level. At present, the wastewater treatment system in Philadelphia has incorporated some elements of the sustainable sanitation theory by harnessing the energy potential within wastewater, rehabilitating its biosolids recycling program, and increasing the pervious area within the city to increase stormwater infiltration. However, nutrient capture and reuse and the absence of decentralized technologies remain an issue. The key obstacles are identified as the legacy of historical decisions that preclude the available options as well as a lack of sufficient knowledge and interest among two key institutions in the decision-making environment, the Philadelphia Water Department and two influential research institutions, the University of Pennsylvania and Drexel University.

Keywords

Urban wastewater, sustainable sanitation, decentralized systems, centralized systems, paradigm, path dependence, closed-loop, reuse & recovery

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List of Abbreviations

BAT	Best Available Technology
BRC	Biosolids Recycling Center
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DEP	Pennsylvania Department of Environmental Protection
DRBC	Delaware River Basin Commission
Ecosan	Ecological Sanitation
Incodel	Interstate Commission on the Delaware River
Mgd	Million gallons per day[1]
NPDES	National Pollutant Discharge Elimination System
OOW	Office of Watersheds
PBS	Philadelphia Biosolids Services
PHS	Pennsylvania Horticultural Society
POTW	Publicly Owned Treatment Works
PRA	Philadelphia Redevelopment Authority
PWD	Philadelphia Water Department
SDWA	Safe Drinking Water Act
SRDC	Schuylkill River Development Corporation
SRF	State Revolving Fund
TMDL	Total Maximum Daily Load
U.S. EPA	United States Environmental Protection Agency
WWTP	Wastewater Treatment Plant

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[1] 1 million gallons=3.78 million liters

1 Introduction

This study investigates the role that wastewater management practices, with specific emphasis on sanitation, play in the long-term sustainability of Philadelphia, a city located along the Eastern seaboard of the United States. The wastewater and sanitation system in Philadelphia is analyzed first from an historical perspective in order to provide the context necessary to understand the internal and external influences guiding the selection and subsequent institutionalization of current wastewater management systems. Using the historical evolution as background and context, the study highlights the current challenges facing the contemporary system as well as the steps being undertaken to address these issues. The concept of sustainable sanitation is discussed and compared against the current system. Environmental, societal and economic issues that are considered vital for the long-term success of the wastewater and sanitation system will serve as the primary criteria for evaluation. Viable yet currently unexplored options that fall under the designation of sustainable sanitation are presented and the challenges to their potential implementation will be outlined and assessed.

Figure 1: Location of Philadelphia, USA

1.1 Background

In his 2008 inaugural address, Philadelphia Mayor Michael Nutter pledged to make Philadelphia the "greenest", most sustainable city in America. Following this ambitious pronouncement, he created the cabinet-level Office of Sustainability and charged it with the task of greening the city in the five vital areas of energy, environment, equity, economy, and engagement.

In 2009, the mayor announced the Greenworks program and placed its directives under the jurisdiction of the Office of Sustainability. The Greenworks Program detailed fifteen specific goals that the city will be promoting and by which the city's progress will be measured. Broadly speaking, these goals pertain to the following areas deemed in need of improvement: waste reduction and recycling; the production of energy from waste products; a natural-systems-based approach to storm water management and combined sewer overflows; increasing access to and demand for locally-grown food; and stimulating the green economy through training programs and stimulus for green business entrepreneurship.

The first annual report released in 2010 describes the significant strides Philadelphia has already made toward meeting each of these goals: that same year the U.S. Chamber of Commerce recognized Philadelphia for being America's top sustainable city ("National honors for city's sustainable development," 2010). In addition, the *Green City Clean Waters* program under Target 7 of the Greenworks plan has garnered national attention for being the first proposal to employ green stormwater infrastructure on so large a scale by an American city. The Philadelphia Water Department's (PWD) plan to tackle the combined sewer overflows (CSO) that are primarily responsible for the city's violation of the *Clean Water Act* included $1.67 billion over the next 25 years for decentralized "green stormwater infrastructure." The PWD is also investing in technology to increase the amount of biogas harnessed from its wastewater.

With this as the backdrop, Philadelphia may have been well poised to reassess holistically the impact of its wastewater system on the long-term sustainability of the city. Even as the city has determined to pursue certain decentralized options for stormwater management, it has also committed an estimated $345 million over the next 25 years to reinvest in the centralized, end-of-pipe treatment system. The primary purpose of this investment will be to increase the system's capacity to handle peak flows, which in severe storm events can be twice that of average flows. This strategy indicates that the city remains wedded to a system that uses water treated to a standard safe for infants, the elderly, and the immuno-compromised to transport a very small amount of waste, one that fails to fully remove or reuse the nutrients within it, and then doses it with chlorine before discharging it into the surface waters. Tackling this issue would mean coming to terms with one of the fundamental underpinnings of a sustainable green city: it will require a radical rethinking of wastewater treatment and a broader environmental vision than the office currently holds.

Wastewater technologies and management options that fall under the heading of sustainable sanitation offer alternatives to the problems facing Philadelphia's centralized wastewater system. Specifically, they address resource recovery and reuse, decentralization, and the need to close the water cycle. Sustainable sanitation technologies have the potential to address, at minimum, five of the fifteen targets stated in Philadelphia's Greenworks plan:

Target 7: Divert 70 percent of solid waste from landfill
Target 8: Manage stormwater to meet federal standards
Target 10: Bring local food within 10 minutes of 75 percent of residents
Target 14: Double the number of low- and high-skill green jobs
Target 15: Make Philadelphia the greenest city in America

Sustainable sanitation technologies are not without their own challenges. Many of these challenges researchers are discovering only now since, compared to conventional systems, the technology is still relatively new. Sustainable sanitation is also an umbrella term covering many types of technologies, from low-tech to very high-tech, not every system suitable for Philadelphia, but all of which would require a step away from the centralized wastewater collection and treatment system to a system that allows for, and encourages, more decentralized approaches. These difficulties are neither easily understood nor easily overcome, yet despite these, there is the potential for huge innovation. This report will seek to investigate that potential in the specific Philadelphia context.

The field work was conducted in Philadelphia and the results submitted and presented at the UNESCO-IHE Institute for Water Education in Delft, the Netherlands.

2 Problem statement

- The city of Philadelphia is currently in violation of the *Clean Water Act* due to an inadequate and aging sewage infrastructure that cannot perform to standard under moderate to severe storm events
- The city's plan to mitigate these effects strongly emphasizes the need to move away from historically established methods of stormwater management by focusing on "green technologies and solutions"
- However, the city does not acknowledge that the current sanitation structure may be unsustainable in the long-run
- No alternative methods to address these problems are included in the city's long-term water management plan

2.1 Research questions

2.1.1 Primary questions

With respect to the long-term sustainability of the city, how does the conventional wastewater system in Philadelphia, Pennsylvania, compare to alternative sanitation options that emphasize decentralization and resource reclamation and reuse?

2.1.2 Supporting questions

Several supporting questions must be addressed before the primary question can be adequately answered. They include:

- What were the internal and external factors influencing the evolution and institutionalization of the conventional wastewater system?
- How is wastewater currently managed?
- What are the challenges this system poses to the Mayor's stated goal of creating the "greenest" American city?
- How are those challenges viewed by stakeholders in wastewater management? What are the plans to meet those challenges?
- What is the structure of the institutional framework governing wastewater? What is the nature of the relationships between primary stakeholders in the wastewater field?
- How is sustainability with respect to wastewater and sanitation defined by the primary stakeholders in Philadelphia? How does that compare to the definition of sustainability of wastewater systems in the literature?
- What alternative, decentralized sanitation systems exist that would be suitable for Philadelphia? What are their relative advantages and disadvantages?
- What are the social, political and normative structures that govern which sanitation options are considered viable and which are ultimately chosen?

3 Methodology

Step 1: Develop theoretical framework to contextualize wastewater management in Philadelphia from an historical, current, and future perspective.

A theoretical framework that draws from the theories of paradigms, path dependence, and new institutionalism will be developed. The theoretical framework will be constructed using a literature review and analysis of seminal works pertaining to these theories. The theories will then be adapted to wastewater management and specifically wastewater management in Philadelphia, drawing upon the work of Novotny et al (2010). The theoretical framework will be a lens through which to analyze the historical development of the wastewater system in Philadelphia, the institutionalization of the current system, and the challenges of transitioning to more sustainable system that occur as a result.

Step 2: Investigate water and sanitation evolution to identify internal and external factors influencing evolution and institutionalization of conventional wastewater treatment system in Philadelphia.

To establish the historical context of water and sanitation in Philadelphia, a thorough analysis of primary archival sources as well as secondary sources will be conducted. The primary sources will be accessed via historical archives made available electronically by the Philadelphia Water Department. Information pertaining to contemporary developments in the history of water and sanitation will be obtained from a literature review of secondary sources as well as from the documents and reports that are accessible via the various responsible agencies. This information will be analyzed and presented in a timeline. The evolution that Philadelphia underwent will be explained via a broader discussion of the rise of the contemporary Western water and wastewater management system. A variety of secondary sources will be consulted to identify the primary drivers for the institutionalization of the contemporary wastewater management system. By clarifying the development water and sanitation in the city itself as well the global context in which it is embedded, it will be possible to analyze the strategies the city employed to address the issues of urban water and wastewater.

Step 3: Identify relevant actors in Philadelphia wastewater management and define their mandate, tasks, and responsibilities with respect to wastewater management.

Identification of relevant actors in wastewater management will begin with a literature review of the legal framework governing wastewater management in the United States. This literature review will make clear the primary actors and semi-structured interviews with those primary actors will allow for the identification of all relevant actors as well as the nature of their interrelationships. The responsibilities of each agent will be fleshed out through the exploration into the legal framework and further clarified through semi-structured interviews.

Step 4: Describe current wastewater treatment in Philadelphia; identify the challenges facing the current system; characterize the future strategies that relevant actors intend to pursue to address these challenges.

Using information made available by the Philadelphia Water Department and the Environmental Protection Agency, including reports, plans, public releases, and other data and documents, the current wastewater management and treatment system will be described. A characterization of the problems currently facing the city will be identified via these documents as well as through semi-structured interviews with PWD employees and knowledgeable academics. The semi-structured interviews in combination with the forward-looking plans will provide answers to questions pertaining to the future of wastewater treatment in Philadelphia.

Step 5: Develop and distribute surveys to actors linked wastewater management in the city to characterize perspective with respect to sanitation and sustainability.

A survey will be developed to establish the position of actors in the wastewater policy community with relationship to sustainable sanitation. The survey will seek to shed light on questions such as: how do the relevant actors define sustainability of the city with respect to wastewater? Using their own definition of sustainability, would they describe the wastewater system in Philadelphia as sustainable? What strategies are important to pursue to ensure that the city remains or becomes sustainable? Is the city pursing those strategies? The answers provided will be analyzed to characterize what sustainability means within the current sanitation paradigm in Philadelphia.

Step 6: Define sustainable sanitation; identify any sustainable sanitation systems currently in place in Philadelphia; describe alternative, viable sanitation systems that are implementable within Philadelphia context but not currently being pursued.

A thorough literature review will provide the information necessary to develop a definition of sustainable sanitation. That definition will then be used to identify any systems that have been implemented in Philadelphia. The sustainable sanitation systems that have been identified will be described and analyzed to understand how and why they were put into practice. Next, sustainable sanitation systems that have been developed in areas outside of Philadelphia, both nationally and internationally, but which are not being implemented in the city will be identified. The alternative sanitation systems will be described via a literature review and information made available by the implementing organizations. Where possible, schematic diagrams will be included in order to showcase (1) how the sustainable sanitation systems differ from the system in place in Philadelphia and (2) what would be required to implement said technologies in Philadelphia.

Step 7: Conduct SCOPUS output comparison between UPENN and Drexel universities and national/international universities of similar size and standing.

SCOPUS output studies will be conducted to establish the degree to which two major research universities in Philadelphia, the University of Pennsylvania (UPenn) and Drexel University, are engaged in the international discussion on sustainable sanitation practices. These results will be compared to international universities of comparable standing. The "Times Higher Education World University Rankings", "U.S. News World's Report Best Universities", and "Academic Ranking of World Universities" databases will be used to identify the rank of UPenn and Drexel and comparably ranked international universities. Using keywords and association searches, differences in water- and wastewater-focused research relative to total article output between Philadelphia's academic institutions and international institutions will be identified. Within articles on water and wastewater, a further keyword search using terms specifically relating to sustainability in water and wastewater management will be conducted to tease out if and to what degree sustainable sanitation is being pursued from an academic perspective. The results will be presented in a table and analyzed for impact and for relative change over time.

Step 8: Using the theoretical framework and research results, explain why alternative methods are not employed and are not mentioned in action plans or on PWD agenda.

Once the initial research has been completed, an analysis will be conducted to establish the reason(s) why any sustainable sanitation systems currently in place have been introduced while also attempting to explain why other systems are not currently implemented in the city and why they are not being pursued. This analysis will draw upon the established theoretical framework, the results from the historical analysis, the results from the SCOPUS analysis as well as the survey.

4 Theoretical framework

A theoretical framework is established below to contextualize the wastewater management in the city of Philadelphia. The framework draws from the theories of paradigms, path dependence, and new institutionalism.

4.1 Paradigms

To understand the evolution of the practice of wastewater management, it is essential to position it within a framework that captures the influence of the prevailing scientific, technical, medical, and social knowledge over time. The paradigm model is a useful tool to accomplish this. The word 'paradigm' traces its roots back to ancient Greece: Plato employed the original Greek word "παράδειγμα" (*paradeigma*) to symbolize a "model, pattern, or example"(Liddell & Scott, 1940).

This original notion of paradigm qua blueprint was elaborated and adapted by American historian and philosopher Thomas Kuhn who in 1962 published his seminal work The Structure of Scientific Revolutions. This work has been credited with establishing the contemporary understanding of the paradigm model as well as the theory of "paradigm shifts." Kuhn explains his understanding of the word "paradigm" as follows: "By choosing it [paradigm], I mean to suggest some accepted examples of actual scientific practice—examples which include law, theory, application, and instrumentation together—provide models from which spring particular coherent traditions of scientific research" (Kuhn, 1962, p. 10). Kuhn argues that science has not evolved along a linear trajectory, but rather as a series of semi-contained scientific epochs, the paradigms, which are defined by a prevailing accepted approach to viewing the world. These epochs are punctuated by periods of scientific revolution, which serve to usher in the next paradigm. Kuhn explains that at any given time the majority of individuals working in the sciences practice what he refers to as "normal science." Normal science is "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice" (Kuhn, 1962, p. 10). That is to say, at any given time, the prevailing paradigm dictates the boundaries within which acceptable science is practiced and defines a specific way of understanding and framing reality.

Paradigms become established if they are seen as superior to competing theories, though the paradigm need not—and indeed cannot—fully explain all of the countervailing facts that may confront it. Once it has been sufficiently recognized as a superior model and the members or practitioners at the time convert to it or rally behind it, the earlier school of thought gradually dies out as a functioning paradigm. As the foundations of a paradigm face mounting challenges by anomalies that subvert the accepted theories of the time, a scientific revolution occurs and the foundations are revised and rewritten. This event he refers to as a "paradigm shift." As Kuhn details, "They [scientific revolutions] are the tradition-shattering complements to the tradition-bound activity of normal science" (Kuhn, 1962, p. 6).

Novotny et al. (2010) believe that Kuhn's concept of the paradigm concept provides a model not only for understanding "how ideas are linked together to form a conceptual framework" *at any given time*, but also for understanding how radical breaks in thinking and radical changes in epistemological standards distinguish conceptual frameworks that emerged at *different times*. The authors use this insight to lay out a chronology of five paradigms of water resource management: (1) basic water supply, (2) engineered water supply, (3) fast conveyance with no minimum treatment, and (4) fast conveyance with end-pipe-treatment and (5) water centric sustainable communities. After characterizing the first four historical epochs, Novotny et al. (2010) describe the future direction of water and wastewater management paradigm, which he terms the era of water centric sustainable communities. The authors classify the paradigms by time period, quality of the receiving waters as a result, and the prevailing approach to water management. Table 1 gives a summary of those results.

Table 1: Chronicle of water management paradigms (*Novotny et al., 2010*)

Paradigm	Time Period	Characterization	Quality of Receiving Waters
1. Basic Water Supply	BC to Middle Ages; still in some developing countries	Wells/surface water for water supply/washing; street drainage for stormwater and wastewater; animal/human feces in streets; privies/outhouses; pervious/semipervious streets	Excellent in large rivers; in small/middle poor during large rains, good between rains; pollutants of concern: fecal pathogens.
2. Engineered water supply	Ancient Crete, Greece, Rome, Middle Ages Europe until industrial revolution	Wells/aqueducts; some potable water treatment; medium imperviousness; sewers and surface drainage for stormwater; some flushing toilets; animal sometimes human feces disposed into street; no wastewater treatment	Excellent to good in large rivers; poor to very poor in small/med urban streams; epidemics; Pollutants of concern: pathogens, lead (in Roman cities because of widespread use of lead, including pipes), BOD of runoff.
3. Fast conveyance with no minimum treatment	From second half of 19th century in Europe/US, later in Asian cities, until second half of the 20th century in advanced countries	Wells/aqueducts for water supply; potable water mostly from surface sources treated by sedimentation and filtration; wide implementation of combined sewers in Europe and North America; beginning of widespread use of flushing toilets; conversion of many urban streams into underground conduits; initially no or only primary treatment for wastewater; secondary treatment installed in some larger US and German cities after 1920s; after 1960 some smaller communities built lower-efficient secondary treatment; paving of the urban surface with impermeable (asphalt and concrete) surfaces; swimming in rivers unsafe or impossible	Poor to very poor in all rivers receiving large quantities of untreated or partially treated wastewater discharges from sewers, runoff discharged into sewers, and CSO, rivers sometimes devoid of O, with devastating effects on biota; waterborne disease epidemics diminishing due to treatment of potable water. Pollutants of concern: BOD, DO, sludge deposits, pathogens
4. Fast conveyance with end of pipe treatment	From the passage of the *Clean Water Act* in the US in 1972 to present	Gradual implementation of environmental constraints resulting in mandatory secondary treatment of biodegradable organics; regionalization of sewerage systems, additional mandatory nitrogen removals required in European community; recognition of nonpoint pollution as the major remaining problem; increasing concerns with pollution by urban and highway runoff as a source of sediment, toxics, and pathogens; increasing focus on implementation of best management practices for control of pollution by runoff; emphasis on nutrient removal from point and nonpoint sources; beginning of stream daylighting and restoration efforts in some communities.	Improved water quality in places where point source pollution controls were installed; due to regionalization, many urban streams lost their natural flow and became effluent dominated; major water quality problems shifted to the effects of sediment, nutrients, toxics, salt from de-icing compounds, and pathogens; biota of many streams recovered, but new problems with eutrophication and cyanobacteria blooms emerged.
5. Water Centric Sustainable Communities	Evolving from the present	Focus on entire sustainable water cycle, beginning with water supply and with used water and solid waste recycle and reuse; term "wastewater" replaced with "used water"; used water and discarded solids serve as resource (electricity, biogas, hydrogen, fertilizer, raw materials for reuse, energy); hybrid (partially decentralized) or full-decentralized water/stormwater/used water systems; on-site water reclamation and reuse, energy and nutrient recovery and other benefits; integrated urban hydrological cycle with multiple uses and functions.	Vast improvements in water quality in point source pollution areas, particularly nutrient loading, as well as areas where fertilizers production is located; agricultural production areas continue to struggle with eutrophication, sediments remain problematic; alternative solutions found for industrial pollutants (de-icing, toxic compounds); biota improved

As the above table demonstrates, the United States is currently operating in the fourth paradigm, though over the past decade that paradigm has faced increasing critique. According to Novotny et al. (2010), "The reality of the fourth paradigm is that after almost 40 years of extensive infrastructure building programs and hundreds of billions spent, the goals of the *Clean Water Act* have not been met." The system we have in place, they argue, is highly vulnerable to extreme events and, ultimately, unsustainable. According to Kuhn's treatise, the simple fact that Novotny et al. are asserting these claims could be evidence that a paradigm shift is about to take place, or is already underway. "Competition between segments of the scientific community is the only historical process that ever actually results in the rejection of one previously accepted theory or in the adoption of another," states Kuhn (p. 8). This work aims to investigate the extent to which the fourth paradigm has stabilized in the city of Philadelphia as well as to understand if and to what extent that paradigm is being challenged and by whom.

4.2 Path dependence

Within the current, i.e. the fourth, paradigm of wastewater management operating in Philadelphia, centralized management seems the only tenable option. At the pivotal moment in time when the vast sewerage networks and systems were being constructed, this was likely true. Since then, the path dependent characteristics of the system have reinforced the belief in the necessity of centralized management via the enormous capital investment sunk into the current system as well as the collective habitus of both practitioners and consumers. The physical infrastructure is undergirded by a conditioned psychological infrastructure. As Quitzau (2007) states, "The processes connected to the planning and implementation of the water supply and sewage systems reflected structural changes in handling human waste, which led to stabilization. A new dynamic equilibrium was reached as a result of using water as a transport medium for human substances".

Path dependence describes a process of development in which the pursuit or choice one faces is limited by the choices made in the past. Simply put, the theory of path dependence means that history matters significantly in determining the choices an actor encounters in the present and the future. In the case of a particular technology, path dependence makes it increasingly difficult to diverge radically from a certain path once it has been selected. The characteristics of path dependence are evident at both the systemic technological level and the level of an individual's daily habit, as the two are intertwined and therefore evolve in tandem (Quitzau, 2007). Quitzau (2007) explains how, "certain systems have path-dependent characteristics, meaning that through specific historical events, such systems become self-reinforcing in the sense of establishing deep-rooted regimes that tend to lock-in or stabilize future development".

The global historical evolution of wastewater management as shown in Table 1 and as replicated in the city of Philadelphia clearly demonstrates that path dependence was and remains a key issue in addressing the issues facing contemporary wastewater systems. The legacy systems in place today have been entrenched for over two hundred years and the engineers and professionals at work today in wastewater management were trained and taught under the theories of the currently prevailing paradigm. As Kuhn (1962) describes, the transition from one paradigm is often fraught with resistance and inertia, because normal science "is predicated on the assumption that the scientific community knows what the world is like. Much of the success of the enterprise derives from the community's willingness to defend that assumption, if necessary at considerable cost" (p. 5).

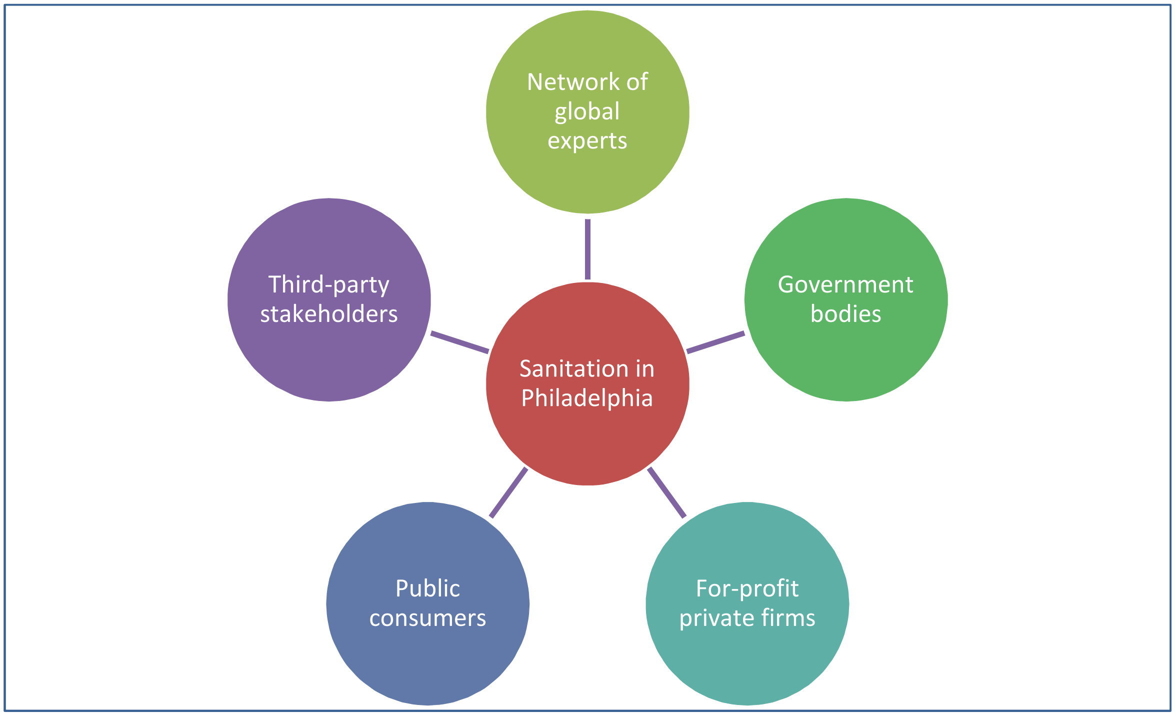
This cost is not just figurative but also literal, a fact that becomes more apparent every year. In 2009, the American Society of Civil Engineers estimated that the aging water and wastewater infrastructure in the United States would require $255 billion in investments over the following five years to meet standards (American Society of Civil Engineers, 2009). The report estimated that only $140 billion had been allocated for the purpose, leaving a shortfall of almost $110 billion. The historical decisions that set America along its current wastewater path will circumscribe the options deemed viable and will greatly inform if and how the country transitions to the fifth paradigm as defined by Novotny et al (2010).

4.3 New institutionalism

Employing the theories of path dependence and paradigms contextualizes the decision-environment. The theory of new institutionalism helps to shed light on the decision makers themselves. New institutionalism posits that policy-making processes can be understood by identifying the institutions that have a role to play and assessing the nature and strength of their interrelated relationships. New institutionalism takes a broad, sociological view of institutions that extends beyond institutions that have been codified, such as government bodies, to include other legitimate and influential entities. According to the theory, the constitution of the institutional environment to a large degree dictates the governing rules, norms and behaviors.

Figure 2 shows the six institutions with bearing on the sanitation system in Philadelphia: (1) the network of global experts, (2) government bodies, (3) for-profit private firms, (4) public consumers, and (5) third-party stakeholders, including academia and non-profit entities.

Figure 2: Diagram of institutions linked to sanitation in Philadelphia



Following the logic of the new institutionalism theory, these actors shape the discourse on sanitation in Philadelphia. Within the network of global experts, sustainable sanitation has undeniably become part of the international conversation on sanitation, of which the United States is an active member. Research on sustainable sanitation systems in the developing and the developed world is being funded by internationally renowned research organizations like EAWAG (Switzerland), GTZ (Germany), the Sustainable Sanitation Alliance (SuSanA) and, most recently, the Bill & Melinda Gates Foundation (Burwell, 2011). In practice, sustainable sanitation has been introduced in Austria, Brazil, the Netherlands, Germany, Denmark, and Finland to name just a few examples (Langergraber, 2005; Lüthi, et al., 2009).

Philadelphia has one of the highest concentrations of academic institutions of any city in the United States with some 80 places of higher education located within or nearby the city. Of these, three are considered major research institutions: the University of Pennsylvania, Drexel University, and Temple University. This project will focus only on the University of Pennsylvania and Drexel University. Drexel University is home to a Sustainable Water Resource Engineering Lab. The University of Pennsylvania approaches the concept of sustainability both from an economic perspective via the Sustainability Program at the Wharton School of Business as well offering degrees in sustainability from the School of Engineering or the Earth and Environmental Science Department.

From this, it would seem that sustainable sanitation should have traction these institutions. It seems more likely that opposition to the concept would come either from private firms, government bodies, or from the public. Private firms profit from their expertise in conventional technologies. The government bodies, particularly the PWD, have capital buried in 3,000 miles of sewer. Alternatively, it could be the public is too uninformed or too unwilling—or perceived to be unwilling—to break with conventional sanitation.

Guest et al. (2009) take a combination of the first and second approaches, arguing that the water industry "has been poorly equipped to address factors outside of the traditional engineering scope...[which] can be traced to the long-standing and narrowly defined approaches that are used to train water industry professionals." Guest et al. (2009) find support with Marsalek et al. (2007) who argue that professional reluctance is a barrier to the incorporation of sustainable sanitation and that new methods of educating professionals will be necessary. Marsalek et al. (2007) go one step further and add that "For such an approach to be viable, it would be necessary to change the current institutional systems, in which the water utility (i.e., the asset owner or operator) is valued according to the infrastructure assets it owns, and the revenue income is based on volumes and pollutants handled". According to him, in this scenario both wastewater volumes and the amount of hard infrastructure required to maintain the system would be reduced.

Jewitt (2011) and Quitzau (2007), while concurring that a revolution of some kind would be required among sanitary engineers and bureaucrats, argue that there are real issues from the perspective of the public—the consumer—to be considered. As Jewitt (2011) states, "the deeply rooted emotions and taboos associated with human waste often occlude rational responses to its disposal, handling and reuse. Unlike flush and discharge systems, [sustainable sanitation] does not allow human waste to disappear into the public domain where it becomes somebody else's problem". Likewise, Quitzau (2007) analyzes the historical development of flush toilet systems and notes that to the consumer sustainable sanitation facilities would likely be seen as a regressive movement, a step backwards in the evolution of humankind towards earlier discarded systems.

5 Literature review

5.1 What is sustainable sanitation?

Within recent decades, the term sustainability has become an all-encompassing word, its meaning as diverse as the people who employ it. Generally, it has come to signify something we agree is a "good" thing that should be "achieved"(Costanza, 1993; Kuhlman & Farrington, 2010). The term connotes a certain vision of the future: to some it has come to symbolize the potential for a "dramatic shift away from the hegemony of profit maximization and economic efficiency to a worldview that seeks a balance between economic development, social equity, and environmental stewardship" (Dilworth, Stokes, Weinberger, & Spatari, 2011). However, because of its ubiquitous usage and because it has been assigned so many meanings, sustainability as a term "runs the risk of ultimately meaning very little" (Dilworth, et al., 2011).

Perhaps the most commonly cited definition can be found in the United Nations' 1987 Brundtland report, which describes sustainability, and more precisely sustainable development, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

The practical implications of the Brundtland definition of sustainable development have been the subject of much research and debate since then. With regard to water resources, two chapters within the United Nations Agenda 21 action plan are devoted to environmentally sound management of freshwater and wastewater. According to the Agenda 21 report, the overarching objective of environmentally sound freshwater management is:

> "to ensure adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases" (United Nations, 1992).

Similarly, environmentally sound waste management must address the "unsustainable patterns of production and consumption" that is at the root of the problem. Under these definitions, the majority of global water management systems would not qualify as environmentally sound. The sustainability of the current "linear approach" to water and wastewater management, sometimes referred to as the *take, make, waste* approach, is facing mounting scrutiny (Daigger, 2009). Increasingly, sustainable water management signifies the incorporation of a circular or closed-loop approach with respect to water, nutrients, and energy.

With a global population of nearly 7 billion that experts expect to rise to upwards of 10 billion over the next four decades, executing sustainable development in practice becomes increasingly complicated (United Nations, 2011). The complexity of managing the anticipated growth in population is made increasingly more so when we take into account that as of 2009 more than 50 percent of current populations live in urban areas and that these urban areas are expected to absorb almost all future population growth (United Nations, 2009). As the global population grows in size and density so, too, will the corresponding stress on the environment. While this seems inevitable, it is possible to imagine that with modifications to existing infrastructure, management approaches, and personal behavior the absolute level of stress on the environment could be mitigated or managed.

Population growth is not the only factor threatening sustainable development. The specific anticipated effects of global climate change vary between scientific bodies, but the general outlook suggests a future of altered weather patterns and increased frequency and intensity of extreme natural events (Meehl, et al., 2007). Beyond this general, if bleak, forecast the science becomes less able to prognosticate specific disasters, although it remains clear that for urban systems to be sustainable into the future, they will need to be able to cope with both increasing population and increasing uncertainty with respect to the global climate (Marsalek, et al., 2007). At present, urban water and wastewater systems across the globe face this challenge.

Within the developed world, the challenge comes in the form of the institutionalized history of centralized water and wastewater system. Alexander Cummings first patented the modern "water closet" or flush toilet over 200 years ago, giving rise to a sanitary revolution that has saved hundreds of millions of lives in the process by keeping individuals safe from disease. Some have heralded Cummings' water closet as the "single greatest contribution to public health over the past 150 years" (British Medical Journal, 2007). Since that time, however, virtually every aspect of modern life has changed while the toilet and the centralized wastewater management system that evolved in tandem with it remain fundamentally the same. As noted in Guest et al. (2009), "Although our understanding of sustainability is constantly evolving, the water and wastewater design process retains its foundation in engineering traditions established in the early 20th century".

The conventional system is flawed in two fundamental ways that can be classified simply as waste and pollution. In terms of waste, the conventional system requires that all water be treated to drinking standards before being piped through vast sewerage networks to dilute and transport a small amount of human waste. Using water as a transportation system is incredibly inefficient. As Speers (2007) writes, "We use tons of water to move what becomes very dilute waste (less than 1 percent is fecal matter) and we have diminished the quality of the transported effluent through the introduction of modern industrial chemicals." Every day in the United States, 32 billion gallons (121 liters) of water transport 100 million pounds (45 million kg) of solid waste through 600,000 miles (965,000 km) of sewer pipes (Praeger, 2007). Every year, the average person using a conventional so-called "flush-and-forget" model will expend approximately 15,000 liters of drinking water to dispose of 35 kg of feces and 500 liters of urine (Quitzau, 2007).

The current system perceives human wastes as simply that — waste. By not recognizing human waste products as a resource, conventional sanitation systems contribute to imbalances in the nutrient cycle, primarily as it pertains to the nitrogen, potassium and phosphorous present in human wastewater. Most urban sanitation systems were designed and built at a time before the science and the policy surrounding the importance of closing material cycles had gained currency and as a result they are simply not designed for that purpose. The reuse of dewatered sludge or "biosolids" from wastewater treatment plants moves in the direction of recovering the nutrients present in human waste. However, the secondary and even tertiary treatment of wastewater often fails to completely remove all nitrates, heavy metals and many toxic chemicals, which then are incorporated back into the environment, often onto agricultural fields (Rockefeller, 1996). Factura et al. (2010) echo this statement when they write, "If sludge from mixed wastewater is returned it has a lack of usable nutrients, the phosphate is to a large extent not accessible to plants because of strong bindings with metal salts from precipitation. Consequently, essential elements, especially carbon, nitrogen and phosphorus but also trace elements are lost, with consequent over-fertilization of water bodies and the seas." Other wasteful elements of conventional sanitation come in the form of energy, labor, and capital, all of which are required in abundance to develop and sustain the current system.

Even with all the resources committed to maintaining the conventional water and wastewater system, many cities are still unable to meet environmental water and wastewater standards. The failure of the current system to fully, or even adequately, protect the citizens or the environment represents the second characteristic of the conventional system, pollution. Combined sewer overflows (CSO) are the result of larger than average volumes of stormwater entering the sewerage network following moderate to severe rain events. The increased volume exceeds the capacity of the infrastructure and forces a combination of stormwater and untreated wastewater to be released into surface water bodies or to backflow into basements. In 2001, the United States Environmental Protection Agency (U.S. EPA) counted some 40,000 such events across the United States (Jewitt, 2011b).

As a result of this confluence of factors as well as the challenge conventional sanitation presents in the developing world, alternative sanitation systems are gaining headway. These alternative systems are often referred to as "sustainable sanitation" or "ecological sanitation" (Ecosan). The term sustainable sanitation encapsulates a variety of sanitation options that propose both economically and ecologically sustainable systems to close the nutrient and water cycles. Sustainable sanitation offers an alternative to the wasteful and polluting nature of conventional sanitation systems. However, sustainable sanitation requires transformations not only in technology, but also in the structure of regulation, management, and stakeholder perception. Essentially, all relevant parties must commit to a movement away from the current wastewater management paradigm, which "focuses on what must be *removed* from wastewater" to a new paradigm "focusing on what can be *recovered*" (Guest, et al., 2009).

Figure 3 below displays the linear path that characterizes the conventional system as well as some of the major problems inherent to it. Figure 4 illustrates that, by contrast to conventional sanitation, the common theme between all forms of sustainable sanitation is the closing of both the nutrient and water cycles coupled with decentralized treatment technology. Sustainable sanitation represents a "holistic approach towards ecologically and economically sound sanitation and is a systemic approach as well as an attitude" (Langergraber, 2005). Daigger (2009) calls for sustainable infrastructure and management authorities that will:

1. Dramatically reduce net water withdrawals for urban uses;
2. Reduce water supply and waste management resource consumption (energy and chemicals), with a goal of energy neutrality; and
3. Significantly improve nutrient management

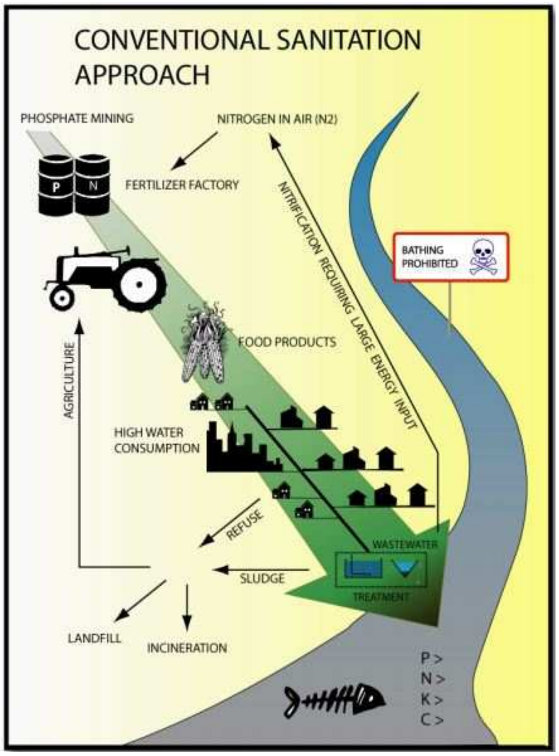


Figure 4: Diagram of Conventional Sanitation (*Koottatep, 2010*)

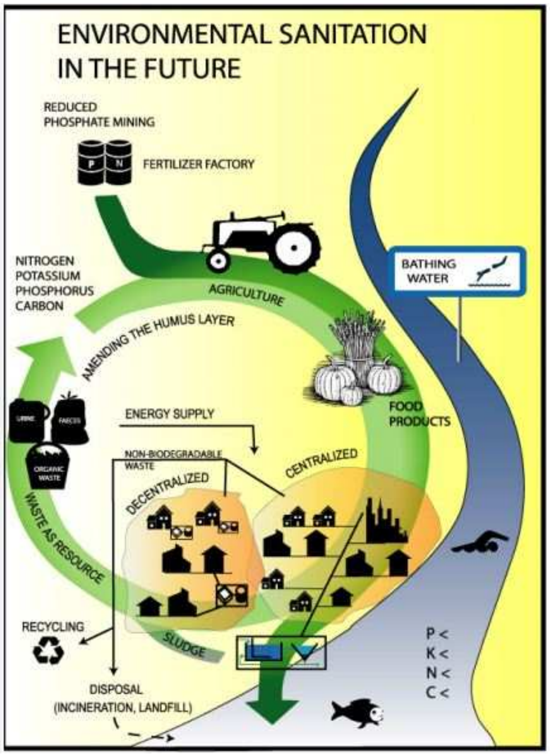


Figure 3: Diagram of Closed-Loop Sanitation (*Koottatep, 2010*)

Much of the literature pertaining to sustainable sanitation technology has focused on its presence in developing world as a potential solution to the sanitation crisis that affects 2.6 billion people worldwide. The reality is that "flush-and-forget" systems are not appropriate for most developing countries and countries in transition due in part to the large financial investment required to build and maintain these systems. However, even experts in the developed world, alarmed at the growing financial burden and ecological impact of maintaining centuries-old conventional systems, are looking for alternatives. If a city is to achieve sustainability, it must be willing to rethink urban infrastructure and the relationship of that infrastructure to its population. The urban infrastructure must be built and redeveloped with the thought that it can contribute to a city's sustainability goals. As Novotny et al. (2010) write, "If planners and developers only think defensively about avoiding or minimizing impacts related to infrastructure (re)development, the "target is lowered," actions become conservative, and the possibility to innovate is greatly diminished"(p. 137).

5.1.1 Resource recovery

The cereal requirement for an adult averages 250kg per year. A human being produces enough fertilizer via urine excretions every year to grow exactly this amount of cereals (Karak & Bhattacharyya, 2011). Few, if any, individuals in the developed world subsist on only 250kg of cereals per year. Nonetheless, the fact remains that human waste contains a substantial and often overlooked quantity of nutrients, potential fertilizer, and energy. As it stands now, nutrients are part of a system that brings resources to municipalities in a one-way flow before being discharged as waste. Mineral fertilizers produced from fossil resources replace the loss of nutrients in agricultural areas (Langergraber, 2005).

Phosphorus is one of those fossil resources. Phosphorus is a necessary element of every living cell: it is a component of DNA, RNA, ATP, and the phospholipids that form all cell membranes. Phosphorus is one of the primary limiting factors governing the growth of many organisms, including human beings and the food we eat. Phosphorus deficiencies are considered the most critical mineral deficiency in grazing livestock as well as being the primary limiting factor in crop production. Phosphorus is also an essential component of products such as explosives, nerve agents, fireworks, and detergents. Approximately 90 percent of phosphate mined is used to produce phosphate fertilizers, with the remaining 10 percent split more or less evenly between animal feed supplements and the miscellaneous products which require it ("Introduction: Phosphate as an Essential Mineral," 2010). Considering the role that phosphorus plays in the production of chemical fertilizers, Dellström Rosenquist (2005) aptly notes that "90% of the phosphorus is used for chemical soil fertilizers [therefore] reuse of excrement (wherein about 90% of the phosphates are retrieved) would make a suitable alternative."

The quantity of phosphate ore—the naturally occurring form of the element phosphorus—is limited. Some experts believe that phosphorus production has already seen its peak. Other experts, while equally convinced of the limited nature of phosphorus, take a slightly more optimistic view, foreseeing between 30 and 345 years before peak production is reached (Cordell, Rosemarin, Schröder, & Smit, 2011; How Long Will It Last," 2008). Within the paradigm of the existing centralized system, however, phosphorus is a waste product, one rarely removed via primary or secondary wastewater treatment, eventually leading to the eutrophication of water bodies.

The case of nitrogen is slightly different. American farmers apply 67 million pounds (30 million kg) of commercial nitrogen-based fertilizer to their fields every day (Praeger, 2007). To produce it, nitrogen is removed from the atmosphere via the Haber-Bosch process, not mined from the earth. Therefore, when it is released through wastewater and wastewater treatment, the nitrogen returns to the atmosphere and the cycle is uninterrupted (Daigger, 2009). Nitrogen production is energy intensive, however, and the inputs required for nitrogen production are limited. As Langergraber (2005) notes, "The reserves of sulphur and oil (used for production of nitrogen fertilizer) are even less [than phosphate ore] and are calculated to last for about 30 and 40 years respectively." Additionally, nitrogen removal from wastewater is an energy-intensive process but a necessary one to prevent the harmful effects of nitrogen in the aquatic environment. According to the U.S. Environmental Protection Agency, of the top three most frequently encountered causes of water body impairments, the presence of nutrients is number one, followed by pathogens and sediments (U.S. Environmental Protection Agency, 2008).

The goal of harnessing the nutrients in wastewater should be a complementary, not alternative purpose of wastewater reuse, write McCarty et al. (2011). The same can be said for reducing net energy requirements. Current wastewater treatment accounts for approximately 3 percent of the United States electrical load (Perry L. McCarty, Jaehoe Bae, & Jeonghwan Kim, 2011). PWD Deputy Water Commissioner Chris Crockett confirmed this to be true in Philadelphia as well, placing the range of energy required for wastewater treatment between 2 and 5 percent (personal communication, March 8, 2012).

The majority of that energy is used to run the aeration tanks, although with modifications to the conventional infrastructure, the energy needs could be reduced dramatically. McCarty et al. (2011) identify three energy-related characteristics of domestic wastewater: "the energy resource contained in wastewater organics, the external fossil-fuel energy requirements for the production equivalent amount of the fertilizing elements [nitrogen and phosphorus], and the energy that might be gained from wastewater's thermal content." To this, one should add the energy requirement necessary to transport water and wastes through labyrinthine piped networks.

At present in the United States, wastewater utilities are beginning to recognize the potential benefit of optimizing systems to harness the energy in wastewater's organic fraction. Far less attention is paid to the other energy costs of maintaining the current system. As an alternative, sustainable sanitation systems cut down dramatically on the requisite distance between production and treatment sites. Sustainable sanitation systems often address the need to capture both the energy and the nutrients within wastewater, sometimes through separation of waste streams to optimize treatment. The recovered energy and nutrients often are utilized at the same geographic scale as the treatment system, in effect closing the energy, water, and nutrient cycles. As Novotny et al. (2010) write, "The core concepts of integration of urban water, resources, and energy management are: (a) there are no wastes—only resources, and (b) optimization of resource value requires an integration of water and energy in addition to ecological and social resilience" (p. xv).

5.1.2 Closing the water cycle

The conventional wastewater system relies on vast quantities on water to facilitate the transport of waste from domestic and industrial points of production to treatment plants and finally to surface waters. Domestic per-capita water demand in the United States is estimated at approximately 240 liters per day without the implementation of water conservation measures. One-third of that total amount, 80 liters per day, can be attributed to toilet flushing (Vladimir Novotny, et al., 2010).

The recognition that freshwater resources and energy are scarce must serve as the foundation of sustainable wastewater management, and so the value of these resources must be expressed in some appreciable and agreed upon unit of measurement. One measure of valuation is the *price* of water, which has historically excluded the inherent and intrinsic value of water. As Guest et al. (2009) note, "Water and wastewater system decisions have been traditionally driven by considerations of function, safety, and cost-benefit analysis. The emphasis on costs and benefits would be acceptable if all relevant factors could be included in the analysis, but unfortunately many relevant factors are routinely excluded."

The sustainable sanitation system aims to reduce the need for such large amounts of water in two ways: (1) by shortening wastewater transport distances to a fraction of what they are in centralized system thereby decreasing the need for large infusions of water to keep the system moving and (2) by decreasing the amount of water needed to maintain the toilets. The recognition that freshwater resources and energy are scarce underpins this approach. This recognition and subsequent institutionalization is a vital component of sustainable wastewater management. With these strategies in mind, one tactic to address these problems would be to incorporate alternative toilet systems. Many toilets in the United States use an average of 13.2 liters of drinking water per flush. Low flow or vacuum flush systems can cut down this amount dramatically. For example, the foam-flush toilet designed by Clivus Multrum, Inc., uses only 3-6 ounces of water for flushing, reducing water use by over 97 percent (Tipping, 2007).

5.1.3 Decentralization

Fundamentally, the long-term sustainability of a city remains in question so long as it remains reliant on "a linear [water and wastewater] system that incorporates long-distance transfer, underground subsurface and deep tunnels, and distant wastewater treatment plants" (Vladimir Novotny, et al., 2010, p. 120-121). Such systems have had, until recently, a virtual monopoly on the thinking of decision makers, urban planners, and engineers. Professionals working in water and wastewater argue that since water is a renewable resource, so long as competing interests are satisfied and water withdrawals are not significantly impinging on recreation, agriculture or aquatic life, economics would dictate that the linear take, make, waste approach remains preferable to closed urban hydrological cycle approaches. This argument fails to account for the fact that "the present practice of wasting potable water and applying it for nonpotable usage... is wasteful and unsustainable in any urban area" (Vladimir Novotny, 2010, p. 286).

By contrast to the linear system that *de facto* relies on inefficient water and energy usage, decentralized systems that distinguish between use type and incorporate local reuse are "highly efficient under any circumstances" (Novotny et al., 2010, p. 286). According to thinkers who champion this new approach, decentralized or "clustered distributed" systems, "should be developed with the reuse of reclaimed water and energy reclamation" in mind (Vladimir Novotny, et al., 2010). These integrated resource management clusters (IRMCs) would be "semiautonomous water management/drainage [units] that [receive] water, [implement] water conservation inside the structural components of the cluster and throughout the cluster, [reclaim] sewage for reuse (such as flushing, irrigation, and providing ecological flow to restored existing or daylighted streams), [recover] energy from used water, and possibly [recover] biogas from organic solids" (Novotny et al., 2010, p. 120-121). In addition to the advantages listed above, the IRMCs would produce comparably smaller greenhouse gas emissions than the conventional alternative that relies on long-distance transfers.

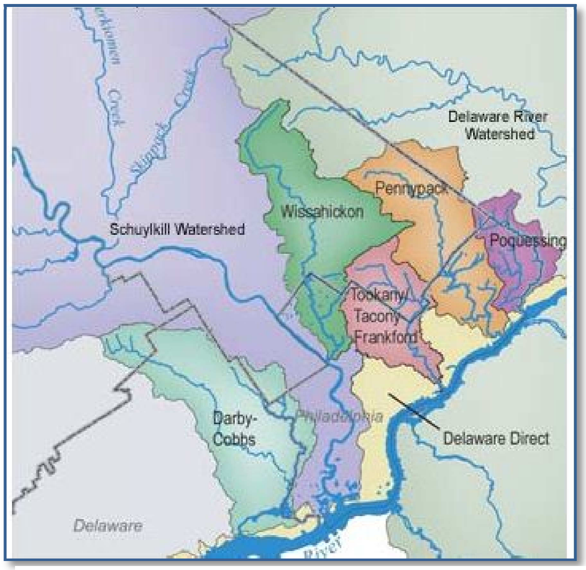
Novotny et al. (2010) assert that as the wastewater industry advances into the future, the reclaimed wastewater loops will shrink from the metropolitan level down to resemble the household or apartment complex or condominium level systems described above. McCarty et al. (2011) second this prediction, explaining that before the recognition of the need for wastewater recycling centralized systems offered economies of scale, but this proves not to be the case moving forward. "Centralized plants are generally located down gradient in urban areas, permitting gravity wastewater flow to the treatment plant," the authors write, "while the demand for reclaimed wastewater generally lies up gradient" (Perry L. McCarty, et al., 2011). Likewise, Schuetze & Thomas (2010) clarify that the barriers to decentralized systems have often been identified as a lack of appropriate technology, innovate system design, poor operational safety, and the high investment and operation costs associated with the transition and institutionalization of a new system. However, they state, research has been able to show that integrated decentralized systems for water and sanitation can be realized without having the above described disadvantages and meeting the requirements for sustainable development, even in existing urban areas with high population density (Schuetze & Thomas, 2010).

6 Evolution of wastewater management in Philadelphia

6.1 Introduction

The city of Philadelphia lies along the Eastern seaboard of the United States, approximately equidistant between New York City and Washington, D.C. The greater Philadelphia region is currently ranked fifth in population among American metropolitan areas. A 2010 census estimated approximately 1.5 million people living within the city's borders. The city has an area of 135.1 square miles (350km^2) with a population density of 10,831 persons per square-mile (U.S. Census Bureau, 2010).

The city is flanked on both sides by the Delaware and Schuylkill rivers, which are the primary sources of drinking water as well as the destination for wastewaters. The city affects seven watersheds, shown in Figure 5: Darby-Cobbs, Delaware, Pennypack, Poquessing, Schuylkill, Tacony-Frankford, and Wissahickon.



even watersheds surrounding Philadelphia

Philadelphia's prime location along the Delaware River and along the Eastern Seaboard has allowed the city to contribute in great measure to the development of the United States. Founded in 1682 by William Penn, the city was designed to serve as both a port and a seat of government. By the 1750s, Philadelphia was the busiest port and largest city in the thirteen original colonies. The Declaration of Independence and the Constitution were signed in Philadelphia in 1776 and 1787, respectively.

In the 19th Century, Philadelphia established itself as a major industrial hub and became known worldwide for its textiles (Macfarlane & Hicks, 1911). Capitalizing on its favorable location and the establishment of the railroad system, the city developed a number of manufacturing industries, drawing upon the large influx of arriving immigrants for its work force. The population of the city continued to grow until it peaked in 1950 at 2.07 million.

In the middle of the 20th Century, Philadelphia began to experience a dramatic population loss, a phenomenon that was repeated across many major industrial cities at the time. This process, known as 'white flight', signaled a movement of predominantly upper- and middle-class white families out of the urban centers and into the expanding suburban regions. Expanding infrastructure, such as highways, encouraged the 'white flight' trends. Within half a century, the population of the city of Philadelphia had declined by 26.7 percent even as the population of the United States almost doubled (*Philadelphia in Focus: A Profile from Census 2000*, 2003).

Philadelphia continues to face demographic and financial trouble. Like other cities that had previously flourished during the early 20th Century industry boom, Philadelphia struggled as the United States' economy transitioned from one based heavily on manufacturing to one where service and expertise were the primary commodities. A report by the Brookings Institution based on the 2000 census found that the city's residents were not reaching the levels of higher education or work force participation compared to other major American cities (*Philadelphia in Focus: A Profile from Census 2000*, 2003). Probably because of these factors, the Brookings report found that the middle class shrunk and household incomes dropped during this period. These socioeconomic troubles echo throughout the city and City Hall and have particular ramifications for the city budgets, which in turn affect the means and the mode of wastewater governance.

6.2 History of water and wastewater management in Philadelphia

Water and wastewater management schemes date as far back in the historical record as the second millennium B.C. Archaeological evidence exists to indicate that the Minoan civilization on the Mediterranean island of Crete enjoyed elaborate systems of water supply as well as both sanitary and storm sewers. The Greek and Roman civilizations that adopted and improved these systems created a network so advanced that according to some scholars they are comparable only to water management systems that appeared in developed countries at the end of the 19th century (Vladimir Novotny, et al., 2010).

In the United States, one need not go so far back in the historical timeline to uncover the origins of the contemporary North American water management systems. Echoing the paradigm structure established above, Burian et al. (2000) list the six factors that contributed in greatest measure to the demise of decentralized management and the rise of centralized management that now defines wastewater management in the United States: (1) failure to keep pace with population growth; (2) construction of public water supplies; (3) public health concerns; (4) limited technology transfer; (5) socioeconomic considerations; and (6) lack of alternative solutions (Burian, Nix, Pitt, & Durrans, 2000). Philadelphia's own historical record bears out this statement. In the case of Philadelphia, modern water and wastewater management begins around the end of the 18th century, with a gift from its most famous citizen and an outbreak of a deadly disease.

6.2.1 Water management

In 1790, realizing that the wells and springs that supplied Philadelphia with water would not suffice for long, Benjamin Franklin endowed the city with a sum of ￡1,000 to develop a piped water supply system from the nearby Schuylkill River. That same decade, 1790-1800, the city experienced a devastating outbreak of yellow fever. The outbreak ultimately claimed the lives of approximately 5,000 Philadelphians, an estimated 10 percent of the population (Levine, 2006a).

Historians now realize that mosquitoes arriving from the West Indies, specifically Haiti, were the disease-carrying vectors responsible for the yellow fever outbreak (Gibson, 2002b). At the time, however, it was believed that wells contaminated by privies, cesspools, and gases (miasmas) were responsible for the outbreak. This belief ultimately spurned the citizenry to petition the City Council to provide "good wholesome Water for drinking & Culinary purposes & for the occasional flooding of the Streets of this City will be the best means of promoting the Health of its Inhabitants & of correcting the State of our Atmosphere so as to render it less recipient of Contagion" ("Minutes of the Select Council of the City of Philadelphia,1796-1799, Book One,"). On January 3, 1799, the city responded by forming the "Joint Committee of the Select and Common Councils for Supplying the City with Water", or Watering Committee, charged with providing water to its citizens citywide, making it the first major city in the world to do so (Gibson, 2002a).

In their quest to provide the citizenry with water, the "Watering Committee" contracted with a young architect and engineer named Benjamin Henry Latrobe. Latrobe would ultimately go on to make a name for himself as the designer of the United States Capitol building, in addition to many other notable contributions to the American architectural landscape. In 1799, Latrobe presented his *View of the Practicability and Means of Supplying the City of Philadelphia with Wholesome Water* in which he outlined a strategy of using wooden pipes to distribute water throughout the city from the Schuylkill River (Benidickson, 2007, p. 62). Despite challenges, the project was completed in 1801 and served as a benchmarking model for other cities of the era.

Not long thereafter, it became clear that the hollow logs transported an insufficient quantity of water, maxing out at one million gallons per day (3.78 million liters/day). In response, the city decided to convert its distribution network to cast-iron pipes in 1819, a difficult process that ultimately took three decades to complete (Benidickson, 2007, p. 63). By the early 1900s, Philadelphia was one of several American cities distributing upwards of 200 gallons (760 liters) per-capita of untreated water per day, levels that greatly exceeded the per-capita production in Europe and the United Kingdom at the time (Benidickson, 2007, p. 73)

6.2.2 Wastewater management

The first storm sewers in the city were installed beginning around 1740 to supplement the above-ground drainage system to protect the city from flooding. These initial underground systems, usually constructed of brick, were considered a benefit to property owners who were required to cover a portion of the costs. Records of this construction were meticulously kept in ledgers such as the one shown in Figure 6.

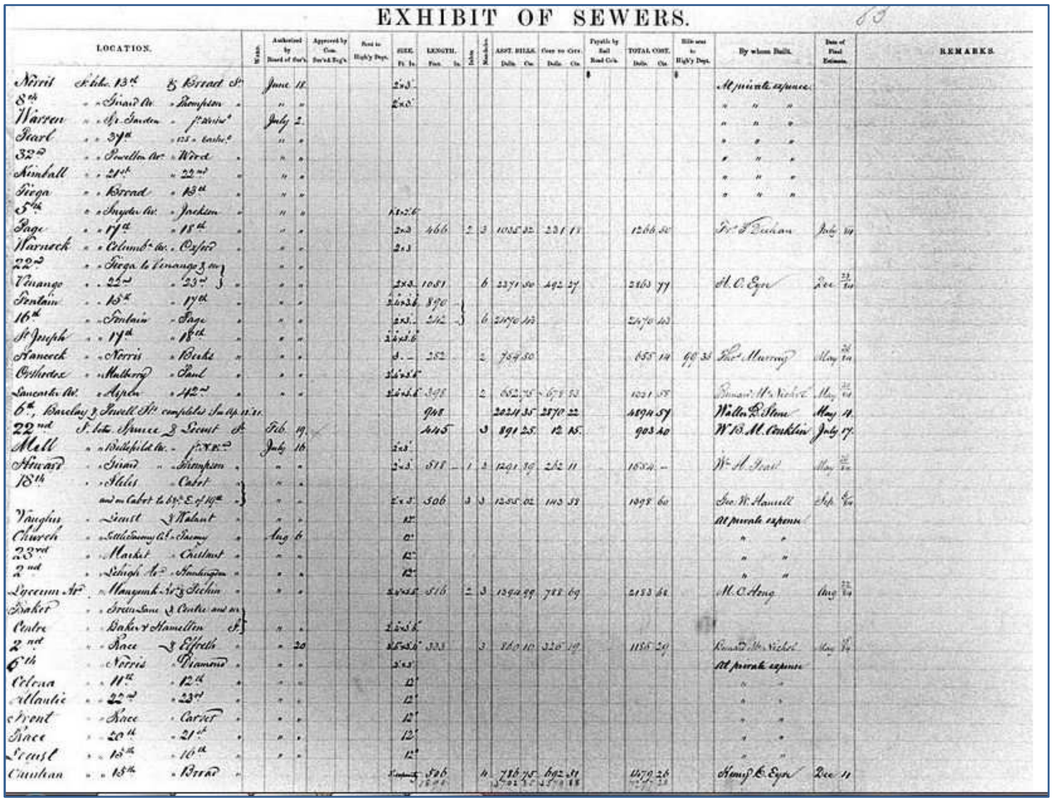


EXHIBIT OF SEWERS.

Figure 6: Record of branch sewers built in Philadelphia, 1867-1885 (*Philadelphia City Archives*)

These early sewer systems were restricted to stormwater only. Human wastes were deposited in privy wells while industrial or commercial wastes were commonly disposed of by dumping into the nearest stream or water body (Levine, 2006c). During this time, privies were cleaned by "nightmen" who were allowed only to do their work at night to minimize the potential deleterious effects of the odors and gases their work produced. The "nightmen" fell under the regulation of the Board of Health whose duty it was to issue work permits. The cost of the permits fell between $0.50 and $5.00. This rule was not always regularly enforced or obeyed, a fact that the Board of Health decried for defrauding the city of revenue as well as operating at unapproved hours. Their response was to hire a Night Inspector whose duty it was to ensure the prevention of the "violation of the Poudrette laws, and in the prevention of the creation of intolerable nuisances at an untimely hour of the night" (*City of Philadelphia Board of Health Report* 1859).

The Poudrette laws referred to the "poudrette pits" that were located on the outskirts of the city, which acted as the dumping ground for the human wastes collected by the nightmen. The wastes decomposed when mixed with material to absorb excess liquid and odor such as charcoal, swamp muck, or gypsum. What resulted was a "poudrette" (from the French for "powder") that records indicate the Board of Health sold to farmers as an agricultural fertilizer (Levine, 2010). This practice remained in place until the American Civil War, after which time the wastes were simply combined with water and directly applied either to agricultural lands or to the market gardens that existed in the more rural parts of the city.

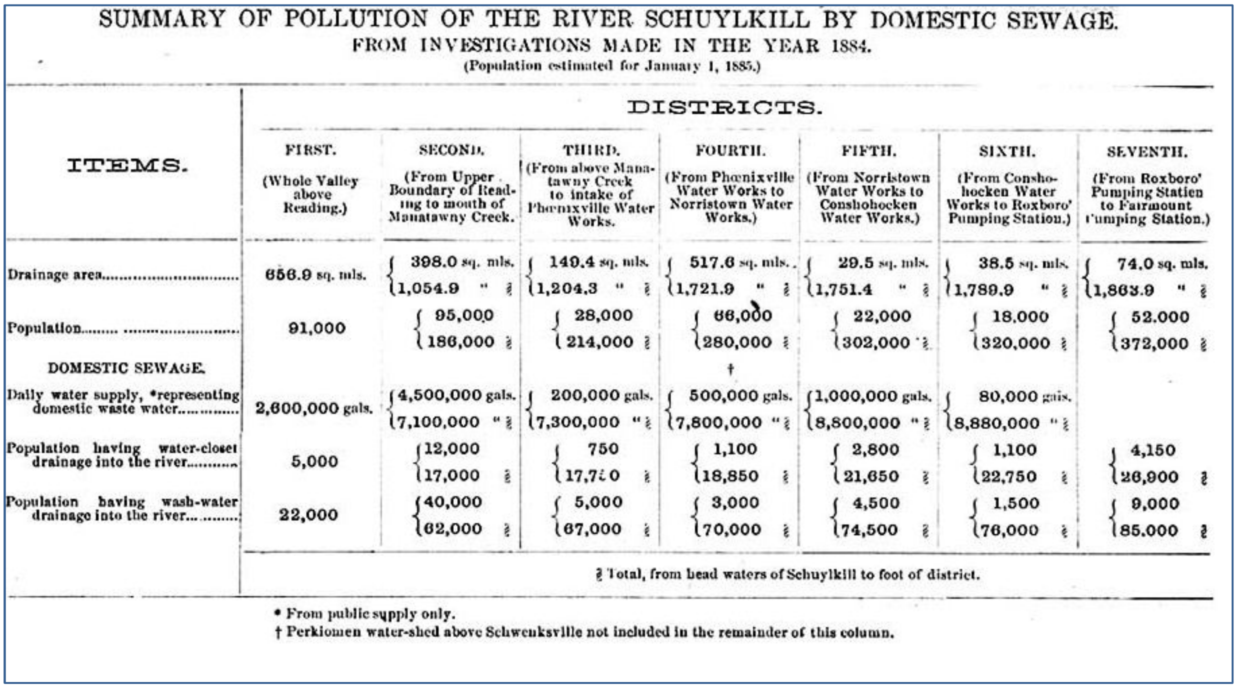
A combination of population growth and increasing per-capita water demand signaled the death knell for the Poudrette system in Philadelphia. In 1854, as the city merged with the surrounding Philadelphia County, the effective city population increased dramatically in size and scope. Between 1800 and 1860, the city's population grew from 81,009 to 565,529; the city limits expanded from two square miles (5km^2) to 130 square miles(336km^2) (Levine, 2006b).

The infrastructure to provide water to this expanding population grew as well. With the introduction of piped water connections to households, appliances such as bathtubs and water closets, forerunners of the modern toilet, came into use, particularly gaining in popularity following the end of the American Civil War in 1865. As a result, domestic water use and wastewater production increased dramatically. The privies, which had been designed primarily for dry wastes, were now connected to water closets and were incapable of handling such increased loads (Levine, 2010). Consequently, they regularly overflowed.

In 1875, the Board of Health adopted a resolution abolishing the emptying of privies by horse and cart and mandated that a system employing "air-tight apparatus", "pumps", and "hose" be put in place. According to then Mayor William S. Stokely, the resolution would "put an end to a disgusting nuisance, and relieve the city of the opprobrium which has tarnished its reputation" (*City of Philadelphia Board of Health Report*, 1876).

Around the middle of the 19th Century, large pipes built primarily in enclosed streams transported most of the waste and disposed of it directly in the Delaware and Schuylkill Rivers. Approximately 200 miles of streams in Philadelphia were transformed into buried sewers during this period (Levine, 2010). In the period between 1855 and 1900, Philadelphia's underground sewerage network expanded from 35 miles (56km) to over 1,000 miles (1,609km) (Levine, 2010). The untreated waste would be transported via the sewers to one of the more than 100 discharge points along the Schuylkill and Delaware Rivers, as well as their tributaries (Levine, 2010). This contamination combined with the industrial wastes from textile mills, tanneries, paper mills, iron works and others that routinely disposed of their wastes directly into the rivers (Levine, 2006b).

By 1884, the Schuylkill River was receiving at least 8.8 million gallons (33.6 million liters) of domestic wastewater per year (Figure 7). As Figure 7 below demonstrates, data on the domestic water supply representing wastewater is missing from one district, District Seven. District Seven includes the area from the Roxboro Pumping Station to the Fairmount Pumping Station and represents the second largest number of individuals having water closet drainage to the river and wash water drainage to the river of all seven districts. We can assume that the contribution of District 7, which covered the city of Philadelphia, would be significant, and therefore that the actual amount of domestic wastewater spilling into the Schuylkill each year would have been significantly higher than the almost 9 million gallons (33 million liters) tabulated.



SUMMARY OF POLLUTION OF THE RIVER SCHUYLKILL BY DOMESTIC SEWAGE.

FROM INVESTIGATIONS MADE IN THE YEAR 1884.

(Population estimated for January 1, 1885.)

ITEMS.	DISTRICTS.						
	FIRST. (Whole Valley above Reading.)	SECOND. (From Upper Boundary of Reading to mouth of Manatawny Creek.	THIRD. (From above Manatawny Creek to intake of Phœnixville Water Works.	FOURTH. (From Phœnixville Water Works to Norristown Water Works.)	FIFTH. (From Norristown Water Works to Conshohocken Water Works.)	SIXTH. (From Conshohocken Water Works to Roxboro' Pumping Station.)	SEVENTH. (From Roxboro' Pumping Station to Fairmount Pumping Station.)
Drainage area..............................	656.9 sq. mls.	398.0 sq. mls. 1,054.9 " §	149.4 sq. mls. 1,204.3 " §	517.6 sq. mls. 1,721.9 " §	29.5 sq. mls. 1,751.4 " §	38.5 sq. mls. 1,789.9 " §	74.0 sq. mls. 1,863.9 " §
Population.........	91,000	95,000 186,000 §	28,000 214,000 §	66,000 280,000 §	22,000 302,000 §	18,000 320,000 §	52,000 372,000 §
DOMESTIC SEWAGE.				†			
Daily water supply, *representing domestic waste water...............	2,600,000 gals.	4,500,000 gals. 7,100,000 " §	200,000 gals. 7,300,000 " §	500,000 gals. 7,800,000 " §	1,000,000 gals. 8,800,000 " §	80,000 gals. 8,880,000 " §	
Population having water-closet drainage into the river...........	5,000	12,000 17,000 §	750 17,750 §	1,100 18,850 §	2,800 21,650 §	1,100 22,750 §	4,150 26,900 §
Population having wash-water drainage into the river............	22,000	40,000 62,000 §	5,000 67,000 §	3,000 70,000 §	4,500 74,500 §	1,500 76,000 §	9,000 85,000 §

§ Total, from head waters of Schuylkill to foot of district.

* From public supply only.

† Perkiomen water-shed above Schwenksville not included in the remainder of this column.

Figure 7: Summary of pollution of the Schuylkill River by domestic sewage, 1884 (*Philadelphia City Archives*)

This solution to simply remove the wastes via sewers seems short sighted by today's standards. However, it perfectly accorded with the established scientific theory of disease at the time. The miasmatic theory, which prevailed among sanitarians until late into the 19th Century, stipulated that the origins of disease were sewer gases, bad odors and decaying organic wastes. The theory is classified as anticontagionist because those who accepted it did not believe disease was transmittable via person-to-person contact (Benidickson, 2007, p. 101). As Benidickson (2007) clarifies, at that time, "not only was it acceptable for wastes to enter the waterways, it was desirable because the perils of putrefaction and miasmas were thereby removed from population centers" (p. 115).

Water quality in the early 19th Century was determined primarily by mineral content and tests of water 'hardness' and 'softness' (McCarthy, 1987). By mid-century, the focus had shifted to organic solids in public water supplies, fueled initially by sanitarians in the United Kingdom looking to remediate the Thames (Benidickson, 2007, p. 101). Around the 1860s, more sophisticated tests to examine the contribution of nitrogen and albuminoid ammonia to water pollution, two chemicals present in human waste, were developed. By 1880, two German scientists doing independent research identified the typhoid *bacilli,* a discovery that would prove vital for the promulgation of the germ theory of disease. However, it would be years before the germ theory of disease found uncontested validation (McCarthy, 1987).

During this period, as piped water and sewage networks were taking root across the Western world, outspoken critics of water-borne sanitation, such as Henry Moule, advocated the use of the earth closet, an early model composting toilet, to recycle the contents as garden fertilizer. Although the two models competed for many years, the miasmatic theory guided the decision in favor of water-borne systems for their ability to remove odors quickly as well as their ability to move waste from the "private to the public sphere where it became the state's problem" (Jewitt, 2011a).

The implications for public health of such a system quickly became clear. As one historian writes, "From the intestines of the sick, microbes were flushed into the sewers, dumped into the rivers, and then drawn into the reservoirs at the various pumping stations. To complete the deadly cycle, they were distributed in water pipes to households and businesses throughout the city" (Levine, 2010).

The level of pollution in the Schuylkill and Delaware Rivers had gained national notoriety by the late 1800s. In 1883, the *Boston Medical and Surgical Journal* reported on an offer made by one Philadelphian theater owner. The owner had promised a reward of $50 to anyone who could drink one quart of Schuylkill River water every day for ten days without vomiting or dying (Levine, 2006d). The threat of either was real.

Thousands of individuals died from contaminated water between the mid 19th Century and early 20th Century. Over 27,000 people succumbed to typhoid between 1860 when the Board of Health began keeping records of cause of death and 1909 when the city introduced filtration for its drinking water. Four years later, the city added chlorination and Figure 8 illustrates the dramatic effect the introduction of these technologies had on the typhoid mortality rate. The combined filtration and chlorination system cost approximately $35 million, making it the city's largest public works project to date when it was completed (Levine, 2010).

Despite improvements in water supply during this period, the challenges posed by the city's lack of adequate sanitation remained severe. In 1905, Everett G. Hill authored an article in the *Journal of the Franklin Institute* in which he summed up the sanitary problem as both a medical and moral imperative:

> "Can we rightly boast of national civilization when less than 4 per cent of the communities in our country have adopted means for the hygienic disposal of filth; and when the sixth city of the land [Philadelphia] is riddled—under buildings as well as under yards and streets—with cesspools, whose overflow babbles noisily and noisomely in the street gutters?" (Hill, 1905)

Towards the end of the 19th Century, the miasmatic theory of contamination slowly lost ground to the germ theory of disease and on April 22, 1905, the Pennsylvania State Assembly reacted by passing a law banning sewage discharge into state rivers and requiring municipalities to draw up and submit plans for collecting and treating municipal wastes (Levine, 2010). Nine years later, in 1914, Philadelphia published its plan entitled the *Report on the Collection and Treatment of the Sewage of the City of Philadelphia,* a master plan for wastewater management. The plan called for the construction of three sewage treatment plants in addition to the expansion of the number and size of pipes to capture the increasing volumes of discharging sewage.

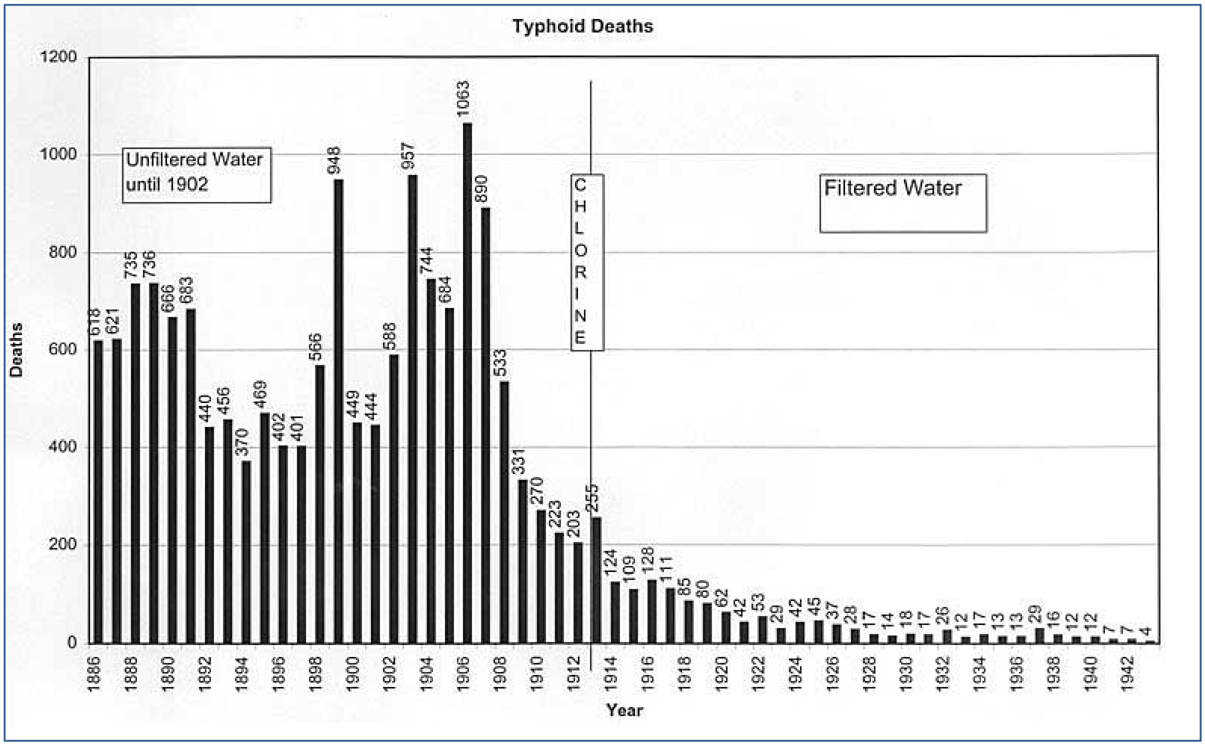


Figure 8: Typhoid Deaths in Philadelphia, 1886-1943
(*Levine, 2006d*)

Over half a century passed between submission of the original plan in 1914 and implementation. Lack of funds was the primary obstacle as the Great Depression and two World Wars sapped taxable revenue and precluded the city from accessing credit. Public opposition to sewer taxes also proved problematic. Sewer taxes were put into place only beginning in 1944. Nevertheless, in 1923, the city managed to finance the construction of the Northeast Sewage Treatment Works (Levine, 2006f). Unsurprisingly, the lone treatment plant was incapable of treating the wastes of the entire city, which by 1929 had reached half a million people. By the 1940s, the daily load of untreated sewage spilling into the Delaware River topped 350 million gallons (1.3 billion liters) (Kauffman, Homsey, Belden, & Sanchez, 2011).

The untreated wastes of so many people and industries spilling into the water bodies produced a horrific stench that even into the 1940s was discernible as far inland as City Hall. The presence of such high levels of bacteria had the effect of lowering the oxygen levels in the river. By the 1950s, the oxygen levels during summer in the Delaware River at Philadelphia were zero, effectively eliminating the potential for aquatic life (Kauffman, et al., 2011). In 1929, one city engineer proclaimed that the lower Schuylkill River was no better than an open sewer, a sentiment captured in Figure 9. The cartoon from a 1937 edition of the *Philadelphia Record* depicts two men in Philadelphia, one wearing 18th Century garb while the other dons a suit from the early 20th Century. The 18th Century man, perhaps intended to portray Benjamin Franklin himself hinting at the role played by historical factors, is plying his modern companion with "Schuylkill Punch", the term used to describe the acrid combination of hyper-contaminated and hyper-chlorinated water. The title reads "Water, Water Everywhere. But Not a Drop Fit to Drink."

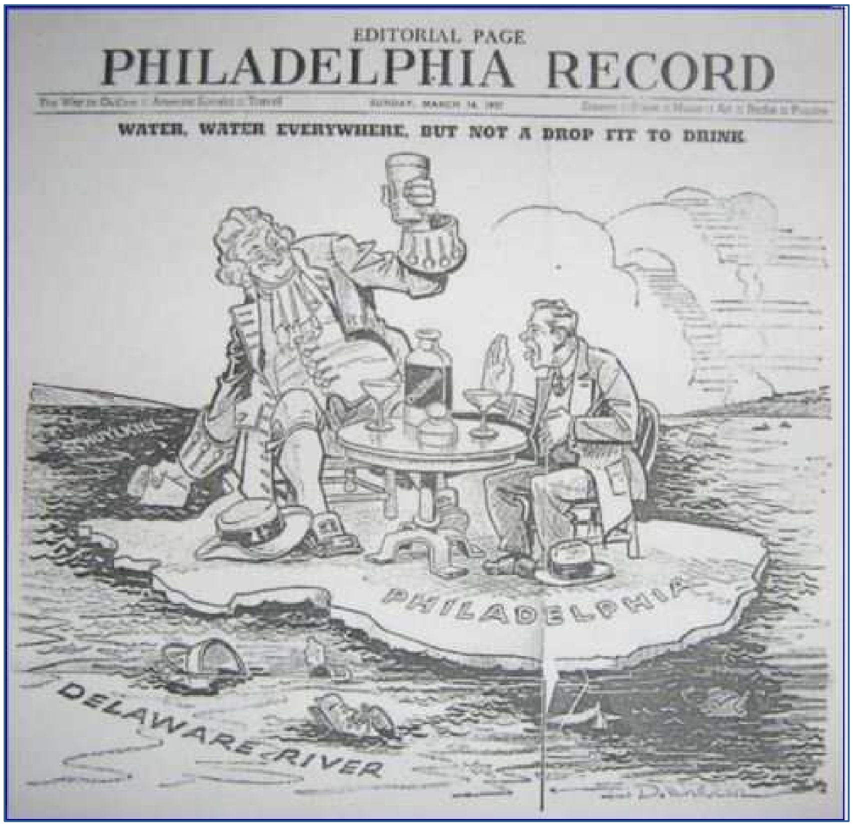


Figure 9: The term "Schuylkill Punch" was a common moniker for drinking water in the early 20th century, referring to the combination of pollution and heavy chlorination, 1937
(*Philadelphia City Archives, cited in Kramek & Loh, 2007*)

The combination of sewer taxes and federal loans that became available around mid 20th Century allowed the wastewater management plan from 1914 to progress more rapidly and construction of the three treatment plants was completed in the 1950s (Kramek & Loh, 2007). The timing of construction coincided with the population peak in the city when the city's population was expected to continue growing. When that proved false, the city found itself with components of its wastewater treatment plant that had been grossly over designed. Once again, with a price tag of several hundred million dollars, the total cost of implementing the wastewater management plan set new financial records for the city (Levine, 2010). The map in Figure 10 details the layout of the sewerage network and treatment plants, which was published in the 1914 management plan and remains an accurate representation of the system still in place today.

The treatment process employed at middle of the 20th century guaranteed only partial removal of solids and bacteria. The Southeast and Southwest Wastewater Treatment plants were built to operate only to primary level, thereby removing between 25 percent to 40 percent of biological oxygen demand (BOD). Even in the 1950s, however, the Northeast plant operated up to secondary treatment level (Levine, 2010).

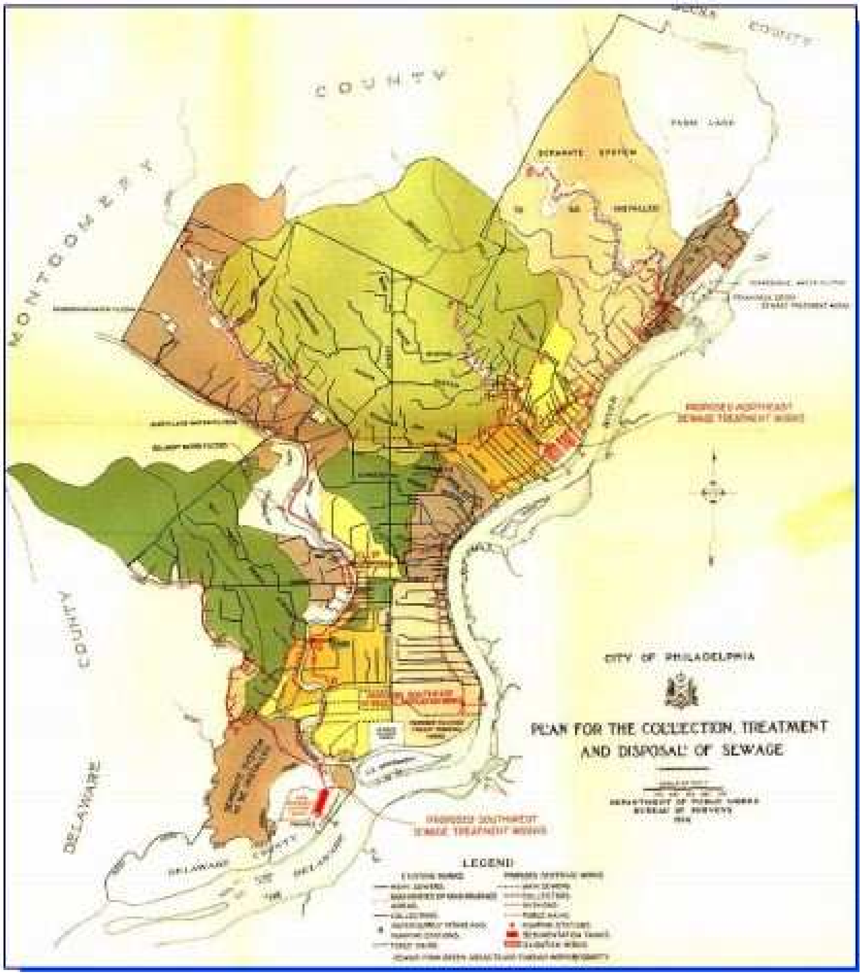


Figure 10: Map included in 1914 master plan of interceptor sewers and three wastewater treatment plants
(*Philadelphia City Archives, cited in Kramek & Loh, 2007*)

As early as 1922, officials in New Jersey and Pennsylvania had tried to establish a cooperative working environment to improve sewage treatment along the Delaware River. Legislation on specific interstate collaborative efforts failed twice in 1925 and 1927 (Benidickson, 2007, p. 301). Only in 1937 with the establishment of the Interstate Commission on the Delaware River Basin (Incodel) were all four representative states (Pennsylvania, New York, New Jersey, and Delaware) finally brought together to address the worsening situation in the river.

What ultimately sprung out of these deliberations became the *Reciprocal Agreement for the Correction and Control of Pollution of the Waters of the Interstate Delaware River* (Benidickson, 2007, p. 301). In it, the states established four zones along the river, dependent on the variations in land and water usage. All municipal sewage systems as well as new industry were required to meet minimum standards, thereby preventing a further decline in Delaware River water quality. It was agreed that "the water, and any material henceforth placed in that water, should be free of floating solids, acids or toxic substances, and possess [an] acceptable oxygen content" ("Interstate Commission on the Delaware River Basin (INCODEL) "). The responsibility for monitoring along the zones fell to the Boards of Health of each state.

As part of this agreement, officials of the city of Philadelphia had stated that $3 million per year would be used to implement the sewage collection and disposal that had been outlined in the 1914 plan. The city remained in default of this agreement until the 1950s. The duties of INCODEL were transferred in 1961 when President John F. Kennedy created the first Federal-State water compact, the Delaware River Basin Commission (DRBC). The responsibilities of the DRBC included "planning, conservation, utilization, development, management, and control of the water resources of the Delaware River Basin" ("Delaware River Basin Commission,").

The *Clean Water Act* followed a similar iterative legislative process. On June 30, 1948, the United States Congress passed the *Water Pollution Control Act*, the stated purpose of which was to "recognize, preserve and protect the primary responsibilities and rights of the States controlling water pollution" (quoted in Benidickson, 2007, p. 307). The *Water Pollution Control Act* granted the Surgeon General, in cooperation with other agencies at the federal, state, and local level, to "prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters" (U. S. Fish and Wildlife Service). To realize these goals, Congress made available $22.5 million annually over five years to subsidize the construction or improvement of treatment works (Benidickson, 2007, p. 307). However, the effort proved toothless, lacking in substance and enforceability. Eight years after the initial passage, President Dwight Eisenhower signed the amended version. Even the amended 1956 version only saw a single action brought to court under the Act, one more than had been prosecuted under the original Act (Benidickson, 2007, p. 309).

In response to increasingly vocal concern for fish and aquatic wildlife, the 1970s ushered in an era of extensive federal expansion with respect to environmental control. The *Federal Water Pollution Control Act* (*Clean Water Act*) was passed in 1972 and later amended in 1977 and 1987. The *Clean Water Act* (CWA) expanded the purview of the *Water Pollution Control Act* beyond the point-source discharges from municipalities and industries to include non-point sources such as agriculture and forestry. Following the passage of the CWA, the two treatment plants in the southern part of the city were expanded to include secondary treatment in order to meet the more stringent standards. The process involved to meet these standards took 15 years and cost the city an additional $1 billion (Levine, 2006e).

The CWA was one of several pieces of federal legislation pertaining to water and wastewater that were passed during this period. Closely after the passage of the CWA, the *Safe Drinking Water Act* (SDWA) of 1974 and the *Pennsylvania Stormwater Management Act of 1978* (Act 167) were incorporated into the legal code. The SDWA acts as the principal federal law governing the drinking water quality in the United States. Act 167 mandates that each Pennsylvanian county draft and implement a stormwater management plan for each designated watershed. The original intention of Act 167 was to stimulate counties to prepare for the potential effects on runoff of possible future development. More recently, however, officials note that scope of Act 167 is broadening as the stormwater management plans increasingly look to include measures to solve existing runoff and flooding issues (Philadelphia Water Department, 2012a).

In the twenty-five years between 1980 and 2005, a significant improvement was recorded for dissolved oxygen, nitrogen, phosphorus, and sediment along the Delaware River. Of the fifteen gages stationed along the Delaware River and major tributaries, 51 percent remained constant, 39 percent showed improvement, and only 10 percent had degraded in status (Kauffman, et al., 2011). This improvement seems especially remarkable when one considers the exploding popularity of heavy-duty detergents between 1947 and 1970. Indeed, during this period, annual sodium tripolyphosphate production, a compound used in these detergents which were found to be resistant to biological degradation, increased 1000 percent, from 100 thousand tons (90.7 million kg) to over 100 million tons (90.7 billion kg) (Benidickson, 2007, p. 292). In 1990, Pennsylvania joined nearby New York in issuing phosphate detergent bans, leading to a marked decrease in phosphorous in basin streams (Kauffman, et al., 2011). By 2005, dissolved oxygen levels had achieved the fishable water quality standard in a tidal river of 5 mg/L (Kauffman, et al., 2011). Since 1980, improved water-quality stations outnumbered degraded stations by a 4 to 1 margin (Kauffman, et al., 2011). In the nontidal river above Trenton, New Jersey, water quality remains good. Near Philadelphia and in the Schuylkill and Lehigh tributaries, water quality, while improved, remains fair to poor for phosphorus and nitrogen in the tidal estuary (Kauffman, et al., 2011).

Around the 1980s, the city of Philadelphia began to consider alternatives to its sludge management, which at that point consisted of barging the sludge into the Atlantic Ocean for ocean dumping. In 1988, the city built the Biosolids Recycling Center and began its EarthMate composting program that officially ended in 2007.

In January 1999, three separate departments within the Philadelphia Water Department were integrated to become the Office of Watersheds (OOW). The three departments that underwent the transformation included: Combined Sewer Overflow, Stormwater Management, and Sourcewater Protection (Philadelphia Water Department). This agency was charged with the mission to "preserve and enhance the health of the region's watersheds through effective wastewater and storm water services and the adoption of a comprehensive watershed

Table 2: Timeline of water and wastewater management in Philadelphia (1780s-present)

Year	Event
1780s-1800s	Residents believe yellow fever epidemics caused by water. Watering Committee formed in 1799.
1801-1820s	New pumping station and reservoir built at highest point of city, Faire Mount.
1820-1850s	Fairmount Dam and millhouses harness Schuylkill river hydropower.
1848	End of 30-year engineering project: cast-iron pipes with curved connectors to maintain high water pressure.
1855-1890	City purchases land along Schuylkill to protect water supply. Becomes Fairmount park, world's largest urban park.
1860s	Civil War. Industrial development/coal industry. Water managers provide reliable water. Philadelphia becomes 1st major industrialized U.S. city. Typhoid from untreated waste disposal.
1880s-1890s	Medical reports ID contaminated drinking water as source of typhoid. Citizens push for treated water.
1902-1912	City builds 5 filtrations plants. Very expensive. Industrial and domestic wastes still discharged untreated to river.
1913	City treats water supple with chlorine; disease rate plummets. River quality continues to deteriorate.
1914	Master plan for sewer and sewage treatment receives acclaim, not put into place.
1950-1966	City constructs 3 sewage treatment plants, sewers.
1970s-present	Creation of EPA: increasingly harsh gov't regulations spur advances. Stormwater mgmt takes priority. Secondary treatment of WW at $1B cost; 92% removal
1974	Safe Drinking Water Act
1988	Biosolids recycling plant: approx. 65% biosolids recycled, composting program ended in 2007
2009+	Green City Clean Waters Program to manage stormwater and CSOs

management approach that achieves a sensible balance between cost and environmental benefit and is based on planning and acting in partnership with other regional stakeholders" (Philadelphia Water Department).

Most recently, the city created the Office of Sustainability whose Greenworks plan included stipulations for water and wastewater management in the city. The PWD's *CSO Long Term Control Plan* became the *Green City Clean Waters Plan* and detailed the PWD's strategy to address flooding and the consequent CSO problem. As previously discussed, the *Green City Clean Waters* plan focused on stormwater and outlined a strategy to increase the permeable spaces in the city and moved partial responsibility to the large, impermeable complexes around the city through a restructured stormwater pricing schedule. The city's plan also documented their intention to invest hundreds of millions of dollars to enlarge the existing centralized wastewater treatment system.

The *Green City Clean Waters Long Term Control Plan Update* addresses the fact that inefficient household water use adds stress to the system. However, when it comes to outlining the main strategies to create "Green Industry" and "Green Homes", the emphasis is on reducing the stormwater flow and not finding solutions to domestic wastewater production or the problems inherent in centralized wastewater management systems.

Documents available from the Office of Sustainability describe a range of technologies that reduce the amount of wastewater generated domestically, though these come only in the form of recommendations for Green Buildings on the way to LEED certification. The Philadelphia High Performance Building Renovation Guidelines include recommendations for replacing inefficient, older household appliances with more energy and water efficient models. The document even briefly mentions on-site wastewater treatment and reuse under the emerging technologies section. Composting toilets, vacuum-assisted toilets and dual-flush toilets are the three options listed. However, in the final *Green City Clean Waters* plan, there is no discussion of the potential for or incorporation of both low-and high-tech sanitation alternatives despite the fact that these systems are legally permitted under Pennsylvania Code § 73.65 (Commonwealth of Pennsylvania, n.d.).

6.3 Philadelphia and the global sanitation evolution

Philadelphia's water and wastewater management evolution is representative of the developments in water and sanitation that took place across North America and Europe over the same time period. While the driver for change stemmed from a specific local problem, the final solution selected adhered to a global sanitation paradigm, which governed what was considered the best science and engineering at the time. As Benidickson (2007) writes in his historical treatise on wastewater, "Against the backdrop of evolving yet inconclusive scientific appreciation of water quality and its relationship to human health, and alongside various strains of agitation for civic and moral improvement, water-borne waste removal secured deep urban foundations"(p. 107).

Whereas in Philadelphia today, the expectation is for all water flowing through our pipes to be treated to potable standard regardless of use, in the 18th and 19th Centuries, and even into the 20th Century, few individuals "had any real expectation of 'pure' water, for purity was a matter of degree" (Benidickson, 2007, p. 102). According to common law at the time, if cows were willing to drink the water, that was sufficient evidence of the water's purity (Benidickson, 2007,

p. 102). At that time, the onus was not on the state to ensure the purity of drinking water, but rather on the individual to differentiate between types of water and, where necessary, to rely on domestic, household, or manufactory level filtration or chemical purification systems to ensure its quality (Benidickson, 2007, p. 102). Individuals could recognize that although certain water may be too contaminated for drinking purposes, it could still be utilized in the production of tanning, bleaching, or dyeing (Benidickson, p. 102). This change is emblematic of the shift from private responsibility to public liability that evolved in tandem with the water and wastewater paradigms.

In the one-hundred years between 1800 and 1900, the standards of water and wastewater management were essentially solidified, as waterworks systems, flush toilets and waterborne sanitation became the rule rather than the exception. In 1800, only 2.8 percent of the U.S. population was served with water via waterworks systems. Within 50 years, the number of waterworks operations had expanded to eighty-three and served approximately 10 percent of the population. Ten years later, the number of waterworks had reached 136; this number jumped to 598 by 1880. By the close of the century, more than 40 percent of the population was being serviced by over 3,000 waterworks systems (Benidickson, 2007, p. 68-69). Similarly, by 1890, over 6,000 miles (9,656km) of sewers had been installed in U.S. cities with populations of 25,000 or larger. Twenty years later, more than 70 percent of U.S. cities and towns had installed sewerage systems, with over 25,000 miles (40,233km) of sewer installed in cities with populations of 30,000 or more (Benidickson, 2007, p. 114).

The introduction and institutionalization of the flush toilet followed a similar trajectory. Although some flush toilets existed in the U.S. in the early 1800s, the first patents were registered in 1833 (Benidickson, 2007, p. 90). At first, flush toilets existed primarily in the homes of the wealthy though by the 1880s it is estimated that they had been installed in approximately 25 percent of urban households nationwide (Benidickson, 2007, p. 90). Gradually, as installations of flush toilets began popping up in particularly conspicuous locations such as the Crystal Palace for the Great Exhibition in 1951, they "reinforced flushing's grip on the public imagination" (Benidickson, 2007, p. 90). It was not long before the presence of flush toilets and other types of sanitary appliances became the measure by which the civilization of a society was evaluated, a standard that remains true even today. By the close of the 19th Century, many major American cities—New York City, San Francisco, Baltimore, Cleveland, Pittsburgh, Chicago, Boston, and Philadelphia— had passed legislation requiring a water closet for every family or for every three rooms (Benidickson, 2007, p. 93-94).

As in Philadelphia, however, almost none of the sewage that flowed through these many miles of pipes received any treatment until well into the 20th Century. In 1909— just five years before Philadelphia published its plan for improving wastewater management in the city— only 12 percent of all wastewater of sewered communities received any kind of treatment (Benidickson, 2007, p. 126). The reason for this had to do partly with costs and partly with uncertainty regarding the exact effect of treatment. Furthermore, the prevailing belief at the time held that the solution to pollution was dilution and the swifter the stream the "greater the wealth, the health and the hygiene of the city would be", serving as a scientific reassurance that no treatment was necessary so long as water was constantly circulated throughout the urban environment (Swyngedouw, 2006).

These scientific notions of water and wastewater management, pioneered by influential sanitarians such as Edwin Chadwick, were further underpinned by an "emerging vision of social and community advancement" (Benidickson, 2007, p. 69). This vision had medical, moral and political implications. Although the convenience of waterborne systems held great appeal, the sanitary movement relied heavily on the notion that cleanliness was a moral imperative as well as a necessary driver of economic productivity. One sanitarian of the time summed up the sentiment in his statement that "There is no more positive indication of human progress—in the simple and rational acceptation of that commonly misapplied phrase—than a due attention to the inestimable blessings which accompany a copious and unrestricted supply of pure water"(quoted in Benidickson, 2007, p. 106). The foundations of the modern conception of hygiene are predicated on an unlimited availability of water, which itself borrowed heavily from the influences of the deeply Christian morality of the 19th and 20th Century. The infrastructure of water and wastewater irrevocably altered not just day-to-day activities of individuals, but also the cultural understanding of cleanliness and filth, which demanded distance above all else. It also profoundly changed the relationship between the individual and the state. As Hawkins (2006) writes, "Plumbing has altered the disciplines of bodies, the way we manage and map them, and how we experience them as clean... It has also been fundamental to distancing us from any direct role in managing our own wastes" (p. 57).

The size and scope of the projects of water and wastewater infrastructure and the public health reasoning that often propelled them necessitated that they fall under the purview of public works. The ability of public entities to sufficiently dictate the policy of waste and control the problems associated with waste served as a marker of government power and influence. Public institutions "were marshalling to exert a significant influence over personal and domestic behavior, initially as promoters and subsequently as regulators of the culture of flushing"(Benidickson, 2007, p. 83).

The current paradigm of centralized wastewater management straddles the realm between the private modern individual, the public mass, and the fundamental biological human that Hawkins (2006) refers to as the "prepublic individuality." In his treatise on the ethics of waste, Hawkins states that the sewer "may be a great technological achievement, but it is also what *literally* connects [human waste] as a public problem and [human waste] as a private secret... [and] their technical and hygienic effects cannot be isolated from their ethical and social ones." The production of fecal matter occurs in private, as a natural function of the biology of the prepublic individual, but the waste is instantly transformed into a public product— and public problem—via a network of pipes and plants. This explains why failures of the wastewater management system are seen as a failure of the state (Hawkins, 2006). These failures of state affect the aggregate of individual constituents who, in perpetuating the paradigm, contribute to the (inevitable) failure in the first place. For this to take place, for us to "protest about visible urban waste and ocean pollution" it becomes imperative that "our personal waste practices are displaced by the performative demands of being a concerned public" (Hawkins, 2006). Our conversion from private producer to public constituency requires both a generalization and an abstraction of ourselves and our waste products (Hawkins, 2006).

Transitioning from the fourth wastewater paradigm to the fifth will therefore necessarily confront the reality of two centuries of psychological conditioning on how we perceive waste and our role in its production, management, and mitigation. The psychological and cultural positions on waste limit to a great degree the options that are deemed viable, as they have been codified into law via regulation as well as pervade the professional establishment of decision makers and engineers who manage water and wastewater. However, despite the fact that within the current paradigm these prevailing standards for cleanliness seem absolute, they are in fact "naturalized cultural distinctions" that are changeable over time. This is to say, our relationship with waste is not static, but evolves over time in response to new information and innovations, as the historical record shows.

7 Current wastewater management

7.1 General urban water management

The institutions currently involved with wastewater management in the city of Philadelphia include the following: the United States Environmental Protection Agency; the Pennsylvania Department of Environmental Protection; the Philadelphia Water Department; the Philadelphia City Council; the Delaware River Basin Commission; and Synagro Technologies.

United States Environmental Protection Agency (U.S. EPA)

The U.S. EPA is responsible for setting regulatory guidelines for municipal water and wastewater utilities through a combination of federal legislation including the *Clean Water Act* (CWA), the National Pollutant Discharge Elimination System (NPDES), the *Safe Drinking Water Act* (SDWA), and the Combined Sewer Overflow Control Policy.

The CWA applies to all navigable rivers and restricts point source discharges to those facilities that have retained the proper permit under the NPDES. In Pennsylvania, the NPDES is managed by Pennsylvania State Department of Environmental Protection (PA DEP). Additionally, the CWA establishes guidelines for technology-based standards for point-source discharges, requiring that at a minimum all facilities operate with technologies that have been approved under Best Available Technology (BAT) standards. The EPA establishes effluent guidelines for wastewater discharges based on the performance of the BAT. Funding for construction or expansion of Publicly Owned Treatment Works (POTW) is provided primarily through a system of grants for major public works, initially authorized under Title II of the CWA which has since been replaced with the Clean Water State Revolving Fund. The U.S. EPA created a program in 1987 to manage sewage sludge or biosolids and their disposal and reuse, although this program may be administered at the state level.

The CSO Control Policy under the NPDES mandates that each state develop state-wide permitting strategies to reduce, eliminate, or control combined sewer overflows. According to the U.S. EPA, the essential elements of a long-term control plan include the following (United States Environmental Protection Agency, 2002):

1. Characterization, monitoring, and modeling of the combined sewer system
2. Public participation
3. Consideration of sensitive areas
4. Evaluation of alternatives to meet CWA requirements using either the "presumption approach" or the "demonstration approach"
5. Cost/performance considerations
6. Operational plan

7. Maximizing treatment at the existing publically owned treatment works (POTW) treatment plant
8. Implementation schedule
9. Post-construction compliance monitoring program

Pennsylvania Department of Environment Protection (PA DEP)

The PA DEP Water Division operates with an annual budget of approximately $28 million. Of this, over $12 million annually is in the form of federal grants to administer the following federal legislation: Clean Water Act, Safe Drinking Water Act, Water Quality Management Planning, Water Infrastructure Security and Operator Training Reimbursement programs. An additional $10 million per year falls into the category of operating budget and is placed in a General Fund. Approximately $5 million per year is spent administering the Pennsylvania Sewage Facilities Planning and Sewage Facilities Enforcement Grant Programs (Pennsylvania Department of Environmental Protection, 2012).

The Office of Watershed of the PA DEP is responsible for administrating the technical program responsibilities for PA Act 537 Sewage Facilities Act. Act 537 covers municipal planning, biosolids programs, on-lot treatment technology review and approval, and on-lot sewage permits. Under the Office of Watersheds, the PA DEP sets permit requirements for water and wastewater treatment technology and design standards, including collection, conveyance, storage, and ancillary facilities. The PA DEP is also responsible for implementing the U.S. EPA's NPDES Program. This mandate includes drafting guidelines for point-source effluent quality for both municipal and industrial wastewater operations. The PA DEP also calculates water quality based on point-source effluent limitations through established water quality modeling protocols (Pennsylvania Department of Environmental Protection, 2012)

The Environmental Quality Board (EQB) is an independent board within the PA DEP responsible for adopting the PA DEP regulations. The EQB is comprised of 20 individuals with the State Secretary of the Department of Environmental Protection as the chairperson.

The Philadelphia Water Department (PWD)

The primary purpose of the PWD is to "plan for, operate, and maintain both the infrastructure and the organization necessary to supply high quality drinking water, to provide an adequate and reliable water supply for all household, commercial, and community needs, and to sustain and enhance the region's watersheds and quality of life by managing wastewater and stormwater effectively" (Philadelphia Water Department, 2012b).

The PWD is responsible for setting and collecting tariffs for water and wastewater management as well as for maintaining the system to meet federal, state, and municipal standards. The PWD issues River Conservation Plans, Integrated Watershed Management Plans for each of the seven watershed surrounding the city, CSO Long Term Control Plans, and Source Water Protection Plans for both the Schuylkill and the Delaware Rivers.

Philadelphia City Council

The Philadelphia City Council is the primary legislative body of the municipal government of Philadelphia comprised of 17 total members, ten of which are elected by district while the remaining seven are elected at-large. The term of each member is four years although there are no restrictions on the number of terms each member may serve. The members of the City Council elect a City Council President from among their ranks. The responsibilities of the City Council President include chairing the council meetings, appointing various individuals to the standing council committees of which there are twenty-two, and selecting and providing oversight over most of the City Council employees. The current composition of the city council by party is 14 democrats and 3 republicans.

The drafting of a city ordinance must begin with a bill introduced by a member of the Council, which then must be referred to the appropriate standing committee by the Council President. Before it can be enacted, the bill must be considered at a public hearing and a public meeting, which are held every Thursday in City Hall. From there, the bill must be reported out by the committee, printed as reported by the committee, distributed to the members of Council, and made available to the public. To pass, the bill must receive a majority vote from all Council members and then the approval of the Mayor. The Mayor's veto may be overridden by a two-thirds vote by the City Council (City of Philadelphia, 2009).

The existing standing committees that pertain specifically to wastewater management in Philadelphia include: the Committee on Appropriations, Committee on Public Property and Public Works; Committee on Licenses and Inspections; Committee on Public Health and Human Services; and the Committee on the Environment (City of Philadelphia, 2012).

For project proposals that extend beyond 4 years, the PWD must seek approval from the City Council. However, the authority to set and raise water and sewer rates rests with the Water Commissioner and does not require the approval of City Council.

The relationship between the PWD and City Council is often characterized as a difficult one. Employees of the PWD complain that some members of the Council have been known to block the passage of certain measures for personal or political reasons. These allegations, while unproven, find support in other reports that list the city as one of the six most corrupt in the nation (Junkins, 2011). As Widener University Professor of Political Science J. Wesley Leckrone put it, "Corruption can occur in any community. However, the tolerance, and even acceptance of a political system based on cronyism and self-interest by Philadelphia's elected officials separates the city from other polities" (Leckrone, 2011). Most recently, in response to an announcement by the PWD of plans to increase rates by 28.5 percent over three years, City Council President Darrell L. Clarke proposed a measure to create an independent body that would assume the authority over water and sewer rates (Graham, 2012a). The PWD issued no public comment.

Delaware River Basin Commission (DRBC)

The DRBC, formed by compact and signed into law in 1961 by President John F. Kennedy, was the nation's first joint Federal-State commission to come together to govern a river system. The Delaware River Basin covers approximately 13,539 square miles (35,065km^2) spread out across Pennsylvania, New York, New Jersey, and Delaware. The ex officio members of the DRBC are the acting governors of each of these four states and the commander of the U.S. Army Corps of Engineers North Atlantic Division, who serves as the representative for the Federal government. The DRBC programs include "water quality protection, water supply allocation, flood loss reduction, drought management, water conservation, permitting, watershed planning, and recreation" (Delaware River Basin Commission, 2012).

The DRBC is responsible for ensuring that 3,000 cubic-feet per second (cfs) (84.95m^3/s) flow down the Delaware to flush out Philadelphia's sewage effluent in each tidal cycle and to prevent the salt wedge from migrating far enough upstream to contaminate the city's water intake and to prevent pipe corrosion for industries with upstream cooling water intakes . The DRBC is also charged with maintaining the water allocations proportions that U.S. Supreme Court statute established in 1953. Under this statute, New York City is entitled to 800 million gallons (3.028 billion liters) per day and Philadelphia receives 300 million gallons (1.136 billion liters) per day.

The DRBC is funded by the four state signatories—Pennsylvania, New Jersey, New York, and Delaware—as well as the federal government. As of March 2, 2011, the DRBC called for the following contributions from the states and the federal government to cover its budget: Pennsylvania $893,000 (25%), New Jersey $893,000 (25%), federal government $715,000 (20%), New York $626,000 (17.5%), and Delaware $447,000 (12.5%) (Delaware River Basin Commission, 2012).

However, as of March 2012, the state of Pennsylvania has withheld its second and third quarterly payments and it seems unlikely to pay the fourth (Bauers, 2012c). The state of New York has slowly reduced its payments so that in fiscal year 2013 it intends to pay 40 percent of its agreed-upon share. Both Delaware and New Jersey have paid or are expected to pay, despite earlier threats by New Jersey Governor Christ Christie had to withhold payments (Bauers, 2012a). The political wrangling between Republican Governors Tom Corbett of Pennsylvania and Chris Christie of New Jersey and the DRBC focus on the DRBC's reticence to authorize natural gas drilling in the watershed until regulations could be adopted. Both Governors are eager to open the Marcellus shale gas reserves, which fall into the upper portions of the watershed, for natural gas exploration and drilling (Bauers, 2012c). Adding to the financial troubles, the federal government has failed to pay its share every year but one since 1989, which amounts to a $9 million shortfall (Bauers, 2012a).

Synagro Technologies

Synagro is a private corporation that has been awarded a 20-year renewable contract with PWD to maintain and operate the pelletizing biosolids recycling system. The mandate of Synagro is to "reduce odors; improve site aesthetics; and produce, distribute and market Class A product in full compliance with applicable laws and regulations and at a competitive cost." The new facilities were recently completed and remain city property though they will be fully staffed, maintained, and operated by Synagro, with the exception of the gas and electric bill, which the city pays. The terms of the contract with PWD are for 63,000 dry tons per year, after which point, the PWD must pay an additional amount on a per-ton basis. The majority of the pelletized product will be marketed and sold to various consumers around the nation, with approximately one-third transported to Florida for use in citrus production (Cowley, 2012). Synagro collects the revenue from the sale of the pelletized product, although beyond a certain per-unit price point the city will also collect a portion of the revenue. The per-unit price threshold could not be disclosed during interviews with the water contract managing engineer at the Biosolids Recycling Center.

7.2 Legal framework

Focusing in on sewage and stormwater, the regulatory structure governing wastewater in Philadelphia begins with the United States Environmental Protection Agency (EPA). There are 10 regional EPA offices located across the country. Pennsylvania falls into region 3, along with Delaware, Maryland, Virginia, West Virginia, and Washington, D.C.

The fundamental piece of legislation with respect to wastewater is the *Clean Water Act* (CWA). The overarching goal of the *Clean Water Act* is to "restore and maintain the chemical, physical, and biological integrity of the Nation's "navigable waters"(U.S. Environmental Protection Agency, 2008). When the Act was first passed in 1972, the states and the EPA focused primarily on the chemical contribution to water integrity. Since then, regulators have expanded their focus to include the physical and biological components of integrity, as well, which explains why the scope of the CWA has broadened over time. The major sub-components of the CWA that impact upon wastewater management include the National Pollutant Discharge Elimination System (NPDES), the Combined Sewer Overflow (CSO) Control Policy of 1994, and the Total Maximum Daily Load (TMDL). These regulations are bolstered by mandates under the *Safe Drinking Water Act of 1972* and the *Pennsylvania Stormwater Management Act of 1978*.

Figure 11 diagrams the operationalized CWA as it exists today. The first task involves establishing water quality standards, comprised of designated uses, water quality criteria, and antidegredation provisions. Once these standards are set, tests and monitoring are performed to determine if a given water body is adequately meeting those standards. If it is determined that the water quality standards are being met, antidegredation policies and programs are drafted and implemented to maintain water quality (U.S. Environmental Protection Agency, 2008).

Figure 11: Diagram of Clean Water Act
(*U.S. EPA*)

If it is determined that water quality standards are not being met, a strategy to bring the water body into compliance is drawn up. In many instances, the strategy chosen involves a Total Maximum Daily Load (TMDL) plan. The TMDL plan outlines what level of pollutants allowable to achieve the desired improvement in quality. The TMDL distinguishes among the sources of relevant pollutants to determine an acceptable load level for each pollutant (U.S. Environmental Protection Agency, 2008). The TMDL only pertains to water bodies in which it has been determined that technology-based approaches to combating point-source pollution will not result in the desired water quality levels (U.S. Environmental Protection Agency, 2008).

Once a TMDL plan has been assembled, the agency can begin implementing strategies that have been authorized by the CWA to meet the pollutant loading objectives. The five most prominent strategies utilized include: (1) the National Pollutant Discharge Elimination System (NPDES) permit program; (2) Section 319; (3) Section 401; (4) Section 404; and (5) the State Revolving Fund (SRF) (U.S. Environmental Protection Agency, 2008). Each of these five strategies are intended to address a different issue affecting surface water quality. As there is rarely a single contributor, these strategies are often used in combination.

The purpose of the NPDES is to control point sources of pollution discharging into surface waters. Section 319 covers nonpoint sources of pollution, particularly farming and forestry (U.S. Environmental Protection Agency, 2008). Section 404 addresses dredged or fill materials that are deposited in wetlands or other waters. Section 401 focuses on federal agencies, requiring that they obtain certification from the territory or Indian tribes before they receive permits that would increase pollutant loads into water bodies (U.S. Environmental Protection Agency, 2008). Lastly, the SRF serve as a vehicle for municipalities to access the credit needed to address point sources, nonpoint sources, and other activities that impact water quality (U.S. Environmental Protection Agency, 2008).

The National Pollution Discharge Elimination System regulates wastewater treatment plants through a system of permits issued for a term of five years by either the EPA, the state in which the treatment plant is located, or tribe. The permits outline parameters with respect to discharge limits, monitoring and reporting requirements and, in some instances, include additional specifications to ensure environmental protection from harmful pollutants (U.S. Environmental Protection Agency, 2012). Issues pertaining to wastewater management that fall under the scope of the NPDES include combined sewer overflows (CSO), industrial and commercial facilities, sanitary sewer overflows, peak flows, stormwater, and pretreatment (U.S. Environmental Protection Agency, 2007).

In 1994, the EPA instituted the CSO Control Policy, which built upon the objectives of the 1989 EPA Office of Water's National Combined Sewer Overflow Control Strategy (U.S. Environmental Protection Agency, 1999). The Policy is a "comprehensive national strategy to ensure that municipalities, permitting authorities, water quality standards authorities and the public engage in a comprehensive and coordinated planning effort to achieve cost effective CSO controls that ultimately meet health and environmental objectives" (U.S. Environmental Protection Agency, 1999). The Policy required the implementation of nine minimum technology-based controls by January 1, 1997. For communities with combined sewer systems like Philadelphia, long-term CSO control plans that detailed the municipalities strategies for full compliance with the CWA were also required to be submitted for approval to the EPA.

The *Pennsylvania Stormwater Management Act of 1978* (Act 167) mandates that each county in the state of Pennsylvania prepare and submit a plan which outlines current and future action to mitigate the impact of stormwater runoff(Philadelphia Water Department, 2012a). A plan must be submitted for each designated watershed within each county.

Quantity Charges			
Monthly Water Charge	Water Service Charge per Mcf	Monthly Water Usage	Wastewater Service Charge per Mcf
First 2 Mcf	$32.85	All billable water usage	$22.14
Next 98 Mcf	$26.62		
Next 1,900 Mcf	$24.43		
Next 2,000 Mcf	$18.60		

Figure 12: Philadelphia's decreasing block tariff rates (*PWD*)

The *Safe Drinking Water Act of 1974* (SDWA) includes several stipulations that affect wastewater management. Under the terms of the SDWA, the EPA is required to research and report upon priority unregulated contaminants that are known to occur or expected to occur in public water system. The EPA periodically releases a list of these unregulated contaminants and ultimately decides whether to take further action. The EPA through the SDWA is also responsible for strengthening public water supplies against microbial contaminants through disinfection while also ensuring proper management of the byproducts of that disinfection.

7.3 Overview

The Philadelphia Water Department (PWD) serves 1.73 million water customers and 2.22 million wastewater customers in a four-county area and handles an average of 42 inches (106 cm) of rainfall annually throughout Philadelphia County (Philadelphia Water Department).

The PWD is an unsubsidized public utility that operates at cost (Crockett, 2012). The PWD employs an increasing block tariff structure to calculate water charges, although a 25 percent discount is available to qualifying senior citizens over 65 years old (Figure 12)[2]. Other customers facing financial difficulty and in danger of shut-off may apply for the Water Revenue Assistance Program, which provides a grant up to $200 (Philadelphia Water Department, 2011).

Even though PWD customers are billed for combined water and wastewater, the breakdown between the two services is explained on the bill (Figure 13). Additional wastewater surcharges cover biochemical oxygen demand in excess of 250 mg/l ($0.322/pound) and suspended solids in excess of 350 mg/l ($0.326/pound). Beginning in November of 2008, the PWD began implementation of a four-year, four-stage rate increase. The last of these, enacted in July 2011, increased the price of water by 5.9 percent for residential users whose usage exceeds 700 cubic feet (19.82 cubic liters) per month (Philadelphia Water Department, 2011). The typical monthly water and wastewater bill between July 1, 2011, and June 30, 2012, is expected to be $62.94, an overall increase of $3.49 (Philadelphia Water Department, 2011).

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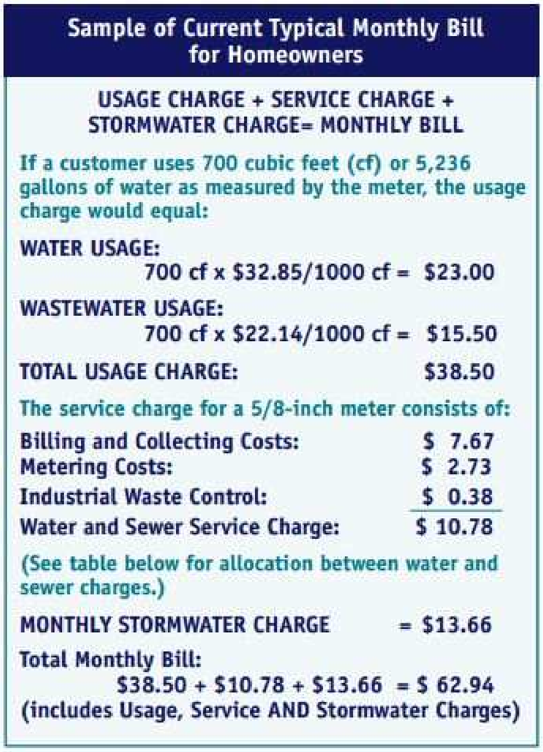
[2] 1Mcf= 1,000 cubic feet ; 28.3 cubic meters



Sample of Current Typical Monthly Bill for Homeowners

USAGE CHARGE + SERVICE CHARGE + STORMWATER CHARGE= MONTHLY BILL

If a customer uses 700 cubic feet (cf) or 5,236 gallons of water as measured by the meter, the usage charge would equal:

WATER USAGE:
700 cf x $32.85/1000 cf = $23.00

WASTEWATER USAGE:
700 cf x $22.14/1000 cf = $15.50

TOTAL USAGE CHARGE: $38.50

The service charge for a 5/8-inch meter consists of:

Billing and Collecting Costs:	$ 7.67
Metering Costs:	$ 2.73
Industrial Waste Control:	$ 0.38
Water and Sewer Service Charge:	$ 10.78

(See table below for allocation between water and sewer charges.)

MONTHLY STORMWATER CHARGE = $13.66

Total Monthly Bill:
$38.50 + $10.78 + $13.66 = $ 62.94
(includes Usage, Service AND Stormwater Charges)

Figure 13: Sample of typical monthly water/wastewater bill (*PWD)*

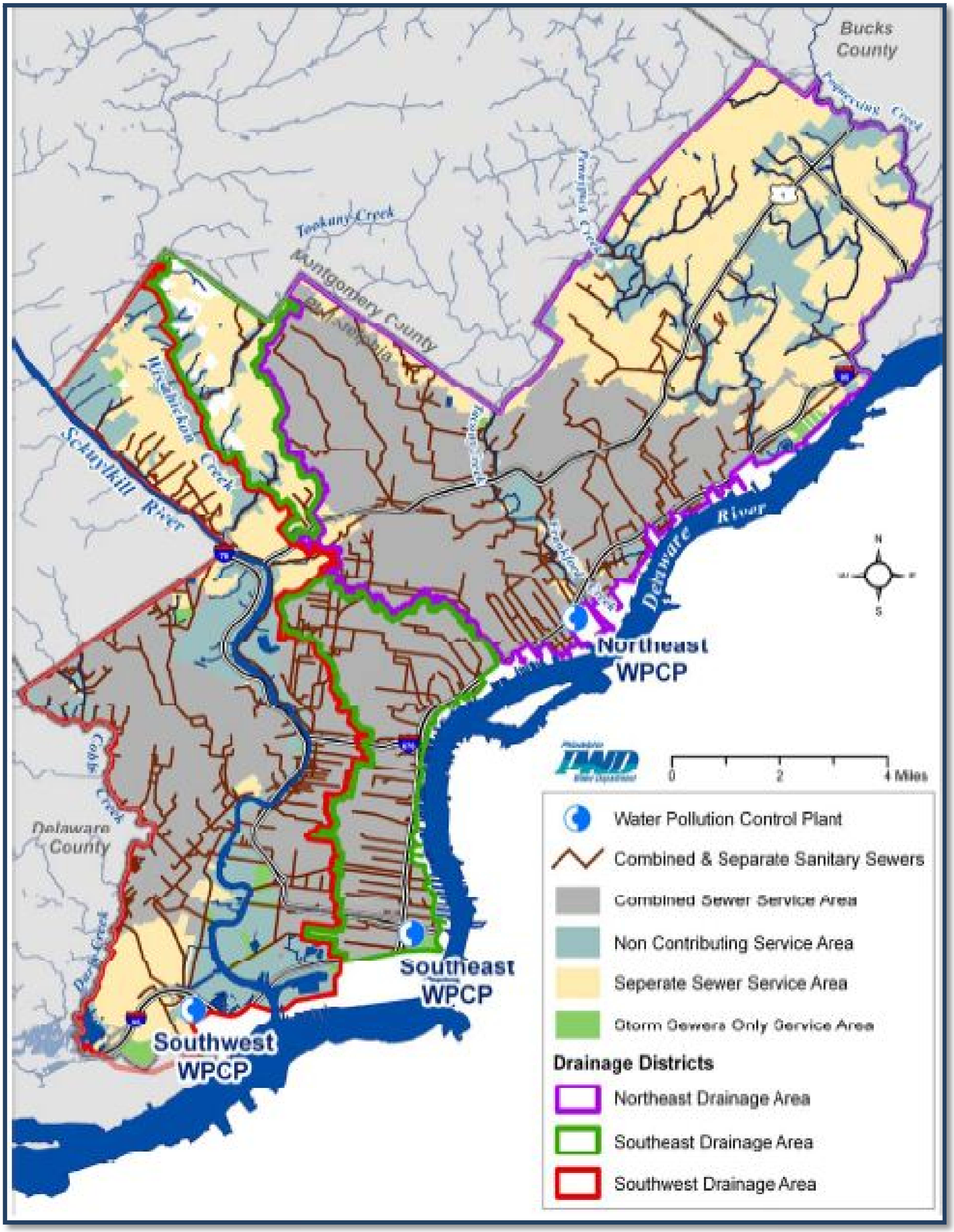
In March 2012, the PWD announced plans to increase rates an additional 28.5 percent, beginning in October 2012. The last stage of the rate increase would take place on July 1, 2015, and would increase the average consumer's annual bill by $196 over today's rates (Graham, 2012b). On a monthly basis, the average homeowner would see increases between $3.52 and $4.75.

The PWD cites an impending $316 million budget shortfall over the next four years as the impetus for the increased rates. The PWD explains the budget deficit as primarily a result of the need to meet federal and state environmental regulations for watershed protection, flood control, and other arenas (Graham, 2012b). While not explicitly stated, it is possible that the PWD foresees federal legislation mandating nitrogen and phosphorous removal on the horizon and has taken that into account as well.

The PWD owns and operates three drinking water treatment plants, three wastewater treatment plants, 450 stormwater outfalls, 160 CSO outfalls, 170 CSO regulating chambers and more than 25 pump stations to serve the city (Philadelphia Water Department, 2012b). The three wastewater treatment plants treat and discharge approximately 1.4 billion liters of treated wastewater daily. Figure 14 shows the location of the Northeast, Southeast and Southwest wastewater treatment plants as well as the distribution of the sewers by type (combined or separated).

The city's wastewater network consists of storm sewers, combined sewers, wastewater treatment plants, also referred to as water pollution control plants, and the Biosolids Recycling Center (BRC). The city has almost 3,000 miles (4,828km) of sewers, ranging in diameter from 8 inches (20.32cm) to 22 feet (6.7m), of which approximately 40 percent are sanitary sewers and 60 percent are combined sewers. The average age of the wastewater lines is a century although date of installation varies by location (Figure 15). The composition of the piped network is approximately 50 percent brick, 25 percent vitrified clay, and 25 percent reinforced concrete pipe (Philadelphia Water Department, 2012b). To ensure the maintenance of the system, the PWD employs a Sewer Assessment Program and on average replaces 8 miles of sewer pipe and 20 miles (32.18km) of water pipe per year. The difference in replacement rates comes down to cost as replacing sewer pipe often involves deeper excavation and different materials (Philadelphia Water Department, 2012b).

ainage areas, and sewers by type



Of the three plants, the Northeast Wastewater Treatment Plant is the oldest. The plant was initially constructed in 1923, was upgraded to secondary treatment in 1952, and underwent reconstruction most recently between 1979 and 1990. The Northeast plant was designed to handle volumes as great as 210 million gallons per day (mgd) (795 million liters/day) but treats approximately 160 mgd (606 million liters/day) of wastewater. Similarly, the Southwest plant was designed for a capacity of approximately 200 mgd (751 million liters/day), but operates closer to 160 mgd (606 million liters/day) (Doug Cowley, personal communication, March 15, 2012). Southwest was constructed during the 1950s and was later expanded and renovated between 1975 and 1983 to meet the tightening federal water pollution control laws set forth in legislation such as the *Clean Water Act* and *Safe Drinking Water Act*. The smallest of the plants is located in the southeast of the city and can treat up to 120 mgd (454 million liters/day) but currently operates closer to 70 mgd (265 million liters/day) (Drew Brown, personal communication, January 20, 2012). The Southeast plant was designed in the 1970s, a time when population in the city was expected to grow dramatically. Since the city's population dwindled over that time, the plant usually operates below capacity (Drew Brown, personal communication, January 20, 2012). Taken together, the three plants treat and discharge around 450-500 mgd (1.703-1.893 billion liters/day) (Philadelphia Water Department).

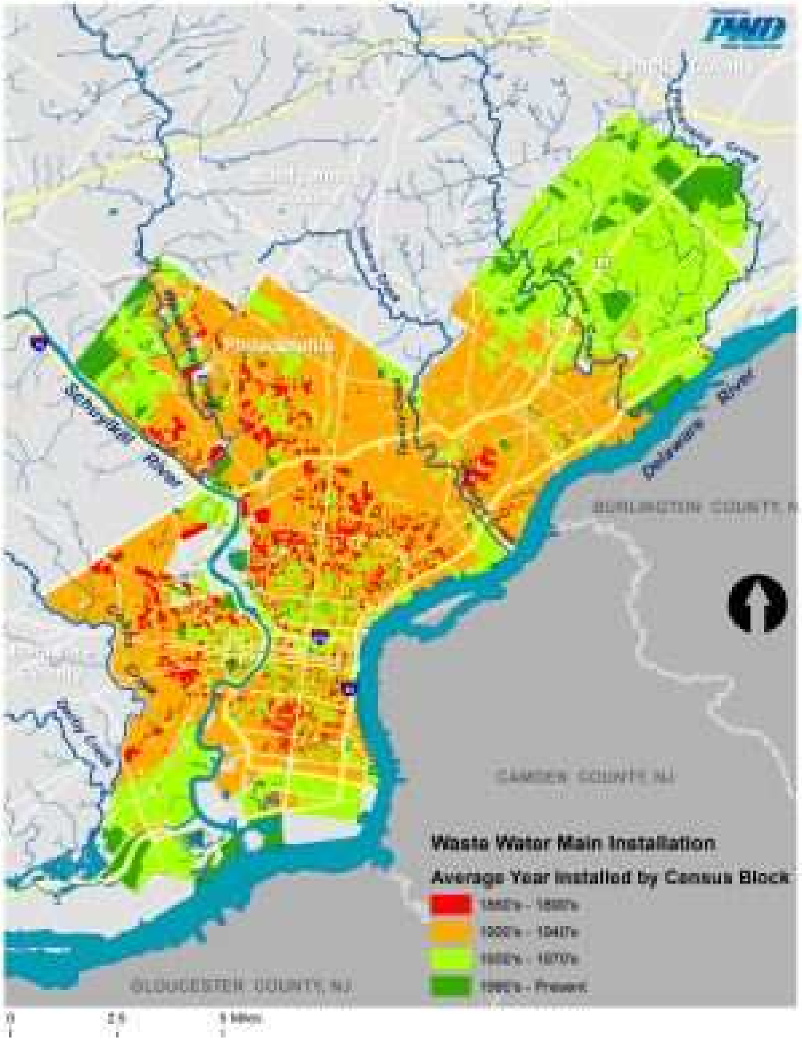


Figure 15: Wastewater main pipe installation by year *(PWD)*

7.4 Treatment process

At present, the three wastewater treatment plants operate to secondary level. Preliminary treatment consists of an initial filtration through sets of bar racks and screens to remove the debris that is later landfilled along with the grit off-site. Drew Brown, Manager of Public Education for the PWD, explained that in certain areas of the city, the stormwater inlets act are treated as the neighborhood trashcan, which results in an unfortunate amount of trash and debris (personal communication, January 20, 2012). Following the initial screening, approximately three-quarters of the wastewater is pumped to meet gravity flow, moving through basins that allow the sedimentation of only the heaviest suspended particles, the grit, to settle.

Following preliminary treatment, the wastewater moves to primary treatment, which uses physical processes to remove between 45 percent and 50 percent of the remaining suspended solids. After primary sedimentation, the settled solids are pumped to digesters and the floating scum and grease are pumped to concentration tanks and landfilled (Philadelphia Water Department).

The mixed liquor then moves to secondary treatment to remove suspended or dissolved organic material. At this stage, the wastewater undergoes activated sludge treatment before flowing to a final clarifier. The settled solids from the clarifier are pumped to another station where they are thickened to between 4 and 5 percent solids and then pumped onward to the digesters. Approximately 40 percent of the methane produced from the digesters is used to heat the digesters. The rest is flared off (Chris Crockett, personal communication, March 8, 2012). The final effluent is dosed with sodium hypochlorite and "the treated water, now cleaner than the river, is returned to the river" (Philadelphia Water Department).

Historically, the primary reasons guiding the selection of chlorine compounds for disinfection was their relatively low cost. As Novotny et al. (2010) write, while "Chlorine provided fast and reliable way of killing off pathogenic microorganisms... after a time, it was realized that the beneficial disinfecting effects of chlorine compounds are outweighed by their adverse effects on human health and ecology" (p. 341-342). Chlorine has the potential to form byproducts through the disinfection process when combined with residual organic substances present in treated water. These substances, known as Tri-halo methanes (THM), are known carcinogens. Chlorine disinfection has also been shown ineffective against protozoan pathogens such as Cryptosporidium or Giardia cysts. The dosages of chlorine required in conventional effluent treatment exceed 20 mg/L, an amount that has been shown to be sufficiently great to adversely affect aquatic life. Since eliminating chlorination from its effluent treatment, the Des Plaines River which receives the discharges from the Stickney Water reclamation plant has improved dramatically (Vladimir Novotny et al., 2010, p. 341-342). In the fifth paradigm described by Novotny et al. (2010), chlorination is "not the disinfectant methodology of choice for water reclamation plants of the Cities of the Future," but is replaced by ozone or ultraviolet treatment. It is worth emphasizing, the authors continue, that "disinfection is not a substitute for high-efficiency treatment" (p. 341-342).

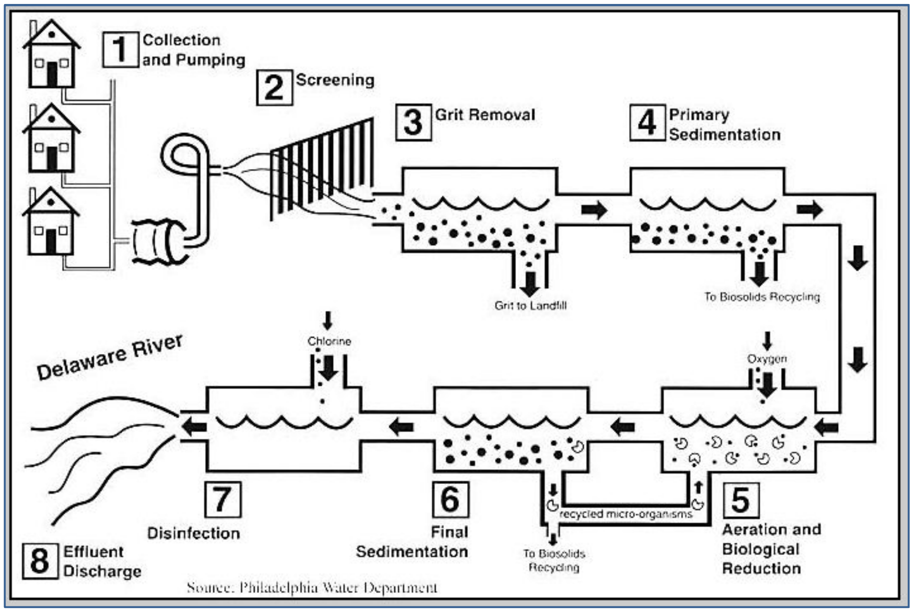


Figure 16: Depiction of Wastewater Treatment Process
(PWD)

Primary sludge from the Southeast Plant is pumped via a connector pipe over to the Southwest plant for digestion. All digested sludge is then processed at the BRC and converted to a Class A pelletized product, over 95 percent of which is sold for various purposes and industries along the East Coast. The pelletization process includes a centrifugal dewatering, a byproduct of which is a centrate with very concentrated levels of nitrogen. The centrate, produced at the BRC, is piped back to the Southwest Treatment plant. At present, however, the wastewater facilities do not include either nitrogen or phosphorus treatment or removal, so the centrate is discharged untreated. This explains why the nitrogen levels in the effluent from the Southwest Treatment plant are dramatically higher than the effluent from the other two plants (Table 3). A PWD employee who did not identify himself explained that nitrogen is the only true cause for concern as the city's wastewater contains such a paucity of phosphorus that in fact phosphorus must be added to the wastewater to facilitate treatment. This lack of phosphorus, according to PWD, can be explained by the fact that ferric chloride is used to treat drinking water, which binds to phosphorus. The PWD anticipates that in the near future the U.S. EPA will take action to regulate nitrogen and phosphorus at which point they anticipate they will implement Annamox technologies into their treatment system.

Plans are currently in development to investigate the possibility for a cogeneration facility at the Northeast Treatment Plant. This cogeneration facility would use the oversized digesters and increase the organic fraction through the addition of slurried food waste. The cogeneration facility, so named to indicate the capture of both heat and anaerobically produced energy, will also be upgraded to utilize OpenCEL technology, which uses ultrasonic pulses to break down the biosolid cell membrane and release soluble material that can be anaerobically digested to produce biogas. According to Chris Crockett, the PWD is expecting a 10 to 30 percent increase in biogas production through the use of this technology, though achieving a 25 percent increase would be enough to make the Northeast Plant energy self-sufficient (personal communication, March 8, 2012). The project is expected to accrue $12 million in energy savings over 16 years by supplying 85 percent of the energy needs at Northeast, resulting in a 15 percent decrease in total PWD energy costs. According to Dr. Crockett, the primary driver motivating innovation in wastewater management moving forward is energy, specifically a need to address the increasing volatility in the energy market as well as the desire for utilities to become independent of the energy grid (personal communication, March 8, 2012).

7.5 Combined sewer overflows

In an average year, Philadelphia receives enough precipitation for 66 moderate to heavy rainfall events, called storm events (Philadelphia Water Department). During these storm events, combined systems exceed their capacity and a mixture of stormwater and sewage is diverted away from the treatment plants and instead released untreated to the local streams and rivers. These events are referred to as combined sewer overflows (CSOs). The impact of these CSOs on the local surface waters is significant.

Of the seven watersheds surrounding Philadelphia, four are within the combined sewer area: Tookany/Tacony, Cobbs Creek, Delaware River and the Schuylkill River. For all four watersheds, impaired water quality in both wet and dry weather has been cited as a major concern. Impaired quality concerns include low dissolved oxygen levels, dramatic fluctuations in daytime and nighttime dissolved oxygen amounts, elevated water temperatures and high fecal coliform levels (Philadelphia Water Department, 2009). Even in areas with separated sewers, potential sewage flows in dry weather and volume control and treatment of stormwater flows in wet weather were identified as major issues. The critical issues raised in both the combined and separated sewer areas indicate an inability of the current wastewater scheme to adequately manage wastewater and stormwater.

Recognizing this, the *Green City Clean Waters* program aims to reduce the 50 million liters per year of untreated wastewater pouring out into surface waters via the CSOs. The CSO problem, which has brought the city in violation of the Environmental Protection Agency's Clean Water Act, would cost approximately $8 billion in conventional infrastructure to repair. Within the paradigm of traditional infrastructure, most cities simply opt to build more and bigger pipes when faced with population growth and the corresponding increase in water use, wastewater generation and impermeable pavement. For example, in the Chicago metropolitan area, approximately 85 percent of the combined sewer overflow passes through the Tunnel and Reservoir System project before treatment at Stickney Wastewater Treatment Plant, the second largest in the world (V. Novotny, 2007).

The *Green City Clean Waters* program approach radically breaks with convention. Instead, the city will spend $1.6 billion, a fraction of the $8 billion estimated under the conventional approach. Half of the $1.6 billion will be invested in green infrastructure, such as green roofs, permeable pavement, stormwater barrels and rainwater gardens, to name a few examples. Almost $350 million will be invested in upgrades to the existing infrastructure. The architects of the plan predict an 80 percent capture of the mixture of stormwater and sewage that would otherwise flow into local rivers and creeks.

7.6 Biosolids production and reuse

In the 1970s, Philadelphia investigated alternatives to ocean dumping as part of an agreement with the U.S. EPA. In 1980, the PWD ended ocean disposal and in 1984 decided to use composting as the principle form of sludge processing. In 1988, the Sludge Processing and Distribution Center opened in the southwest of Philadelphia adjoining the Southwest Water Pollution Control Plan and the Philadelphia International Airport. The Sludge Processing and Distribution Center was later renamed the Biosolids Recycling Center (BRC). Until 2008, the BRC processed the sludge from all three wastewater plants. The combined service population is 2.3 million people (Philadelphia Water Department).

After secondary treatment at the wastewater plants, the sludge underwent a dewatering process to arrive at a composition of 25 percent to 30 percent solids. This formed the final product: biosolids cake. The BRC produced approximately 220,000 tons (200 million kg) of biosolids cake per year (Philadelphia Water Department).

The biosolids cake met both federal and state standard for stability and allowable contaminant levels. The product was used in coalmine reclamation, for public works applications, as part of a compost marketing program and for agricultural utilization within Pennsylvania, Maryland and Virginia. The remaining fraction was landfilled. Figure 17 shows the percent distribution of each of these programs prior to 2008. After March 2007, the BRC ceased production of compost due to difficulties with the treatment, increasing costs and staffing reductions. During the time the composting system was operational, the facilities staff struggled with odors, spontaneous fires, and an inevitable backlog that would build up during the winter months when demand for compost is low (Doug Cowley, personal communication, March 15, 2012).

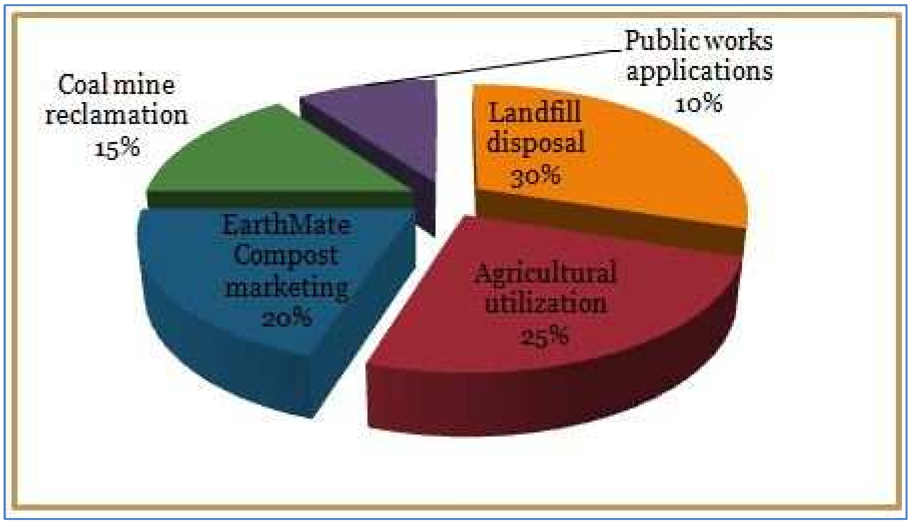


Figure 17: Biosolid reuse programs prior to 2008 (*PWD*)

At the time of its closure, the Title V air management operating permit had expired (Synagro Technologies, 2012). In 2008, Philadelphia Biosolids Services (PBS), a joint venture led by Synagro Technologies, won a 23-year contract for "the comprehensive management of the City's biosolids, including the design, financing, construction, maintenance, and operation of facilities at the City's Biosolids Recycling Center" (Office of Economic Opportunity).

PBS was given responsibility for full operation and management of all biosolids dewatered by the city. Synagro lists the following as benefits anticipated from PBS:

- Managing 100 percent of the city's biosolids into a "Class A" pathogen-free biosolids product that EPA classifies as a fertilizer
- Incorporating a cutting-edge rainwater collection system to reduce both the volume of storm water routed to the wastewater treatment plant and the potable water used by the thermal drying facility
- Minimizing off-site odors and noises
- Reducing greenhouse gas emissions and ensuring compliance with air management regulations
- Shrinking current operations from 59 to 19 acres, allowing the city to recapture property for other productive uses
- Cutting annual truck deliveries by 7,000 per year
- Creating 75 construction positions and 30 long-term jobs
- Saving an estimated $200 million over the life of PBS's 23-year contract with the city

Figure 18: Pelletized biosolids
Pellets reach 65%-70% solids composition

The use of dewatered sewage sludge or "biosolids", while an obvious improvement over ocean disposal, leaves much to be desired. As Daigger (2009) notes, "unless nutrient removal and accumulation in the biosolids is essentially complete, biosolids still allows for significant dispersion of nutrients into the aquatic environment". Applying biosolids to agricultural fields is considered beneficial because of the presence of the nutrients and humus derived from human waste, the same ingredients in the compost derived from resource-oriented sanitation systems. The potential for each of these products to allow pollutants to permeate into the soil and therefore potentially back into the food chain are on different scales of magnitude.

Studies have shown that urine is a substantive contributor of pharmaceuticals and their metabolites to wastewater (Winker, Faika, Gulyas, & Otterpohl, 2008). Therefore, the product derived from sustainable sanitation may contain residues from pharmaceuticals that pass through the human body. The impact of these pharmaceuticals in the natural environment is still to a great degree unknown. However, the product derived from sustainable sanitation systems remains free of the additional harmful elements that enter the conventional wastewater treatment system and ultimately wind up in the biosolid cake. As Price (2009) explains, "biosolids can count as ingredients everything that's dumped into our sewer system...and its long-effects on the soil are impossible to predict". Jewitt concurs, specifying the types of toxic materials that appear in sewage sludge to include heavy metals, oganochlorine oestrogen mimickers (the most well-known of these include DDT, chlordane, PCBs and dioxin), radioactive material from hospitals and phenols (Jewitt, 2011b).

The presence of PCBs has been identified as a major concern within both the Delaware and Schuylkill watersheds (Philadelphia Water Department, 2009). A recent national sampling identified the highest levels of radioactive iodine-131 in Philadelphia's drinking water (Bauers, 2012b). The source of the substance was traced back to thyroid patients who excrete it through their urine. The excreted Iodine-131 then passes through the wastewater system. Monitoring has shown spikes of iodine in the Wissahickon Creek at a point below five sewage-treatment plants that discharge to the creek. Julia Rockwell, the project engineer with PWD's source protection program, was quoted as confirming that "wastewater-plant effluent is a pathway for Iodine-131"(Bauers, 2012b). The levels of iodine-131 remain within the allowable parameters although long-term exposure to high levels can be carcinogenic. The PWD is struggling with how to minimize and control the amount of Iodine-131, one way being a decentralized system that bypasses the centralized system for patients receiving Iodine-131 treatment. It was suggested that patients store their own urine until proper treatment can be applied or until they can bring it back to the hospital for treatment. These options were rejected because they were considered unsanitary and unsafe (Bauers, 2012b).

The nutrient content of these products also differs dramatically. As Rockefeller (1996) argues, the majority of the nitrogen content present in raw sewage is lost during treatment and disposed with the wastewater. For sustainable sanitation systems, with the exception of some losses of nitrogen in the form of ammonia, potentially all of the nitrogen, phosphorous, and potassium from urine and feces could be recycled to agriculture (Langergraber, 2005). Experiments with urine-diverting toilets resulted in an estimated recycling rate of approximately 60 percent of the total nitrogen load, the rest being lost through incorrect usage or equipment malfunction (Hochedliner, et al., 2008).

8 Sustainable sanitation technologies

Sustainable sanitation is characterized by closed-loop approaches to water, nutrients, and other resources, within a decentralized system. Systems that meet this definition cover a broad spectrum of potential solutions, from low to high tech. Having established the professed advantages of the sustainable sanitation approach, the following chapter describes the result of investigations into the degree to which alternative technologies have been implemented in Philadelphia in contrast to other comparable locations. Additionally, an analysis of the research conducted to establish the knowledge base with reference to sustainable sanitation is presented. This analysis draws upon the results of the survey, which was distributed to individuals within the wastewater policy community, as well as the SciVerse SCOPUS published materials survey.

8.1 Locally implemented projects

Central to the primary research question of this project was the extent to which sustainable sanitation technology has been implemented in Philadelphia. An initial literature review to locate any published academic or newspaper materials on the existence of sustainable sanitation was conducted. This search resulted in a discussion of the waterless urinals in the LEED-certified Comcast Building. Following this, the question was posed to a variety of individuals whose positions would indicate that, should such technologies exist in the city, they would be those most likely to be aware of the existence. This list includes: Eileen Gallagher, Citywide Project Manager at the Pennsylvania Horticultural Society, who works closely with Philadelphia's urban farms (personal communication, November 15, 2011); Johanna Rosen and Joe Revlock, managers of the various urban farms which were revealed to have implemented composting toilet technologies (personal communications, November 5, 2011; January 13, 2012); Joanne Dahme, Glen Abrams, and Drew Brown at the Philadelphia Water Department (personal communications, November 25, 2011; November 28, 2011; January 20, 2012); Josh Nims, Operations Manager at the Schuylkill River Development Corporation (personal communication, November 29, 2011); Laura Blau, former president of the Delaware Valley Green Building Council (DVGBC)(personal communication, December 13, 2011); Richard Roark, lead architect at the Olin design firm in Philadelphia which won the Living Cities Design Competition for a design proposal that incorporated decentralized wastewater technologies (personal communication, January 18, 2012); Dr. Franco Montalto, Dr. Charles Haas, and Dr. Patricia Gallagher, professors at Drexel University specializing in water and wastewater technologies (personal communications, January 9, 2012; March 5, 2012; March 20, 2012); Dr. Robert Giegengack, professor emeritus at the Earth and Environmental Science department at the University of Pennsylvania who has a long history of working with the city to rehabilitate the infrastructure (personal communication, October 26, 2011); Dan Garofalo, Environmental Sustainability Coordinator at the University of Pennsylvania (personal communication November 2, 2011); and Al White and Steve Beebee, suppliers of approved composting toilet technologies (personal communications, February 9, 2012; February 10, 2012).

The results of these discussions revealed three composting toilets within the city. It should be noted that the results of this search do not preclude the existence of other systems. Less formalized, ad hoc systems in which a particular individual takes it upon themselves to build a composting or waterless toilet have been documented in other states and therefore the possibility of their existence cannot be ruled out. Nevertheless, given the broad scope of the search, one would expect the total number of additional systems to be small.

All three composting toilets were constructed primarily for the purpose of providing facilities to an area that could not, for practical or legal reasons, connect to the centralized sewerage system. Two of the toilets were financed wholly or in part by the Philadelphia Water Department. Two of the facilities are located in urban gardens, although only one is currently recovering and reusing the product. The managers of all three composting facilities indicated that they had not had trouble with operations, maintenance, or odors (Johanna Rosen, personal communication November 5, 2011; Josh Nims, personal communication, November 29, 2011; Joe Revlock, personal communication, January 13, 2012). Both Johanna Rosen and Joe Revlock, who are responsible for managing the two urban farms, indicated that the individuals who had expressed the greatest interest in the potential of the composting toilets were other urban farmers. Josh Nims, who maintained responsibility for the other composting toilet along the Schuylkill River recreation trail, stated that he had received hundreds of inquiries from a variety of individuals interested in the technology.

8.1.1 Comcast Center

At almost 1000 feet (300m) high, the Comcast Center is the tallest building in Philadelphia. The building, which was completed in 2008, is also the tallest Leadership in Energy and Environmental Design (LEED) certified building in the U.S., having achieved the gold standard for the building's core and shell in 2009. The LEED program, administered by the United States Green Building Council, is the leading rating system for the "design, construction and operation of green buildings" in the United States (U.S. Green Building Council, 2011). Some of the features of the Comcast Center that made it eligible for the LEED certification include water-saving fixtures that save more than 3 million gallons (11 million liters) of drinking water annually as well as 116 waterless urinals that save an estimated 1.2 million gallons (5.4 million liters) annually ("Waterless urinals a go for Comcast Center," 2006).

Despite its water saving potential and proven track record elsewhere in the country, the proposal to incorporate the waterless urinals highlighted one of the major obstacles facing innovative construction in the Philadelphia: the city's powerful unions. The installation of the waterless urinals was strongly opposed by the Philadelphia's Plumber's Union Local 690. The foundation of the union's complaint was the fact that the waterless urinals required less piping, which would result in less work for plumbers. Ultimately, an agreement was struck between the Plumber's Union and building's developed Liberty Property Trust to redundantly install both the waterless systems as well as additional piping that allows for conversion to flush urinals should any problems with the waterless systems arise ("Waterless urinals a go for Comcast Center," 2006).

8.1.2 Mill Creek Farm

Mill Creek Farm, located in the West Philadelphia neighborhood, was the brainchild of co-directors Johanna Rosen and Jade Walker. The name Mill Creek refers to the creek that originally flowed through the area before it was enclosed around the turn of the last century. The housing that was developed atop the enclosed sewer proved to be an unstable foundation and gradually began to subside. In the 1970s, the housing developments were torn down and the land remained vacant, with the exception of a small community garden that took root on the western portion of the property.

Figure 19: Location of Mill Creek Farm, Philadelphia (*googlemaps*)

In 2005, the Philadelphia Water Department coupled with the Pennsylvania Horticultural Society (PHS) and made available the 1.5-acre (6,070 m^2) plot of land for urban farming and the organization was awarded grants from both organizations to fund its start up. The mission of the farm is to "[improve] local access to fresh produced, [build] a healthy community and environment, and [promote] a just and sustainable food system" (The Mill Creek Farm). However, the future of the farm remains precarious. The land remains under the ownership of the Philadelphia Redevelopment Authority (PRA) and is leased to the PWD (Johanna Rosen, personal communication, November 5, 2011). Attempts to place the land into a land trust with the Neighborhood Gardens Association to protect it from future development have been unsuccessful thus far.

According to Glen Abrams, manager of the Strategic Policy and Coordination department at PWD, the primary reason for the installation of a composting toilet on the site was because of lack of a sewer lateral to provide sewer access (personal communication, November 28, 2011). The composting toilet is a BioLet 10 Standard Waterless Toilet, designed for three people using it full-time or four people using it part-time.

According to Johanna Rosen, the contents do not accumulate quickly as the BioLet toilet effectively and rapidly breaks down the solids mass (personal communication, November 5, 2011). When the compost is removed from the toilet, it is transferred to a pile at the base of a

Figure 20: BioLet toilet with educational signs depicting open- and closed-loop nutrient cycles
Mill Creek Farm, Philadelphia

banana tree on the farm along with other organics from the farm to be composted (Figure 21). The banana tree produces no fruit but, according to Ms. Rosen, has proven to be exceptionally well adapted to utilizing and processing the compost (personal communication, November 5, 2011). Whatever excess compost remains is transported to Laurel Valley Soils, a larger composting facility in the region (Johanna Rosen, personal communication, November 5, 2011). The toilet has been incorporated into Mill Creek's educational process, with hanging signs that depict the difference between open- and closed-loop nutrient cycles (Figure 20).

Figure 21: Biolet toilet compost below banana tree,
Mill Creek Farm, Philadelphia

8.1.3 Summer/Winter Garden

The Summer Winter Garden on the corner of Race Street and 33rd Street in Philadelphia has been part of the Powelton Village community since it was first created in 1977. Following a decision by the Philadelphia Redevelopment Authority to demolish the buildings and industrial developments that once stood where the garden now lies, a group of ten families located on the Summer and Winter streets that border the garden made the decision to redevelop the land together. The garden was later expanded to include the entire city block (West Philadelphia Landscape Project, 1997). At present, the land is still owned by the PRA, which leases the property to the Summer/Winter garden for $1 per year.

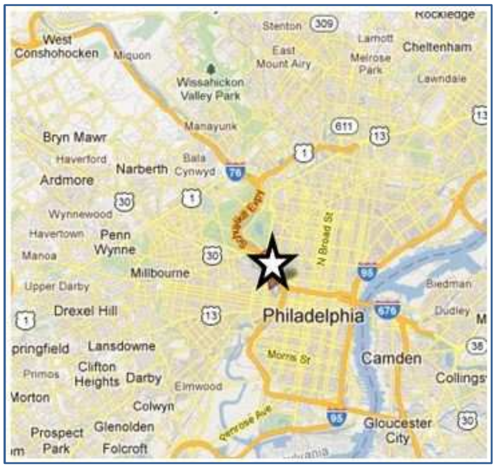


Figure 22: Location of Summer/Winter Garden
(*googlemaps)*

Figure 23: Joe Revlock, manager of the Summer/Winter garden, and the BioLet toilet facility

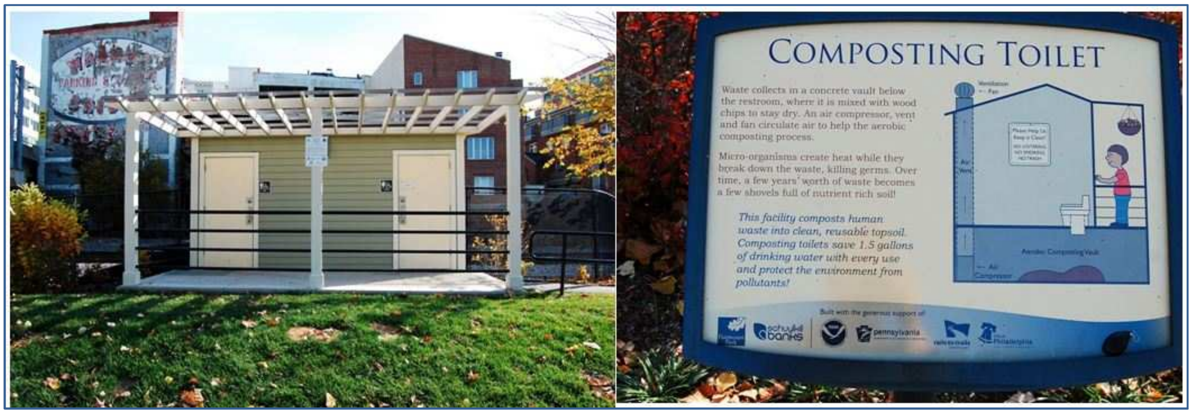
Since moving to the neighborhood in the late 1970s, resident Joe Revlock has taken over the majority of the management of the Summer Winter garden. For the majority of the years that he has been involved with garden, Mr. Revlock allowed the garden members to make use of the toilet facilities within his home on the corner of Summer Street (personal communication, January 13, 2012). When the community began a children's garden program, it became clear that they needed a more dependable system available to them even when Mr. Revlock was not at home. Three years ago, at the suggestion of Mr. Revlock who investigated the various options available, the gardeners decided to incorporate a BioLet toilet onto the site, the same brand that is currently utilized at the other urban farm, Mill Creek (Joe Revlock, personal communication, January 13, 2012). The Neighborhood Gardens Association provided financing for the toilet and its installation. Mr. Rosen locks up the facilities during the winter once the temperature drops below 60° F (personal communication, January 13, 2012). He says this is the third year that the toilet has been at the Summer/Winter garden and thus far he has not had to remove the compost because it breaks down so quickly and because the garden itself is relatively small and thus accommodates only a limited number of members (personal communication, January 13, 2012). Mr. Revlock indicated that he prior to implementing the toilet on the property, he did not attempt to receive permission from the PWD (personal communication, January 13, 2012).

8.1.4 Schuylkill River Trail

The other PWD-financed composting toilet is located along the Schuylkill River trail, which is managed by the Schuylkill River Development Corporation (SRDC). The SRCD is a non-profit entity focused on redeveloping and renewing the lower Schuylkill River area in Philadelphia. Perhaps their most notable project is managing the Philadelphia section of the Schuylkill River Trail, which begins in Center City and follows the river past Philadelphia monuments such as the Philadelphia Art Museum, Fairmount Water Works, and Boathouse Row, into

Figure 24: Location of Schuylkill River Trail composting toilet
(*googlemaps*)

the communities of Mananyunk and Conshohocken.


COMPOSTING TOILET

Waste collects in a concrete vault below the restroom, where it is mixed with wood chips to stay dry. An air compressor, vent and fan circulate air to help the aerobic composting process.

Micro-organisms create heat while they break down the waste, killing germs. Over time, a few years' worth of waste becomes a few shovels full of nutrient rich soil!

This facility composts human waste into clean, reusable topsoil. Composting toilets save 1.5 gallons of drinking water with every use and protect the environment from pollutants!

Figure 25: Composting toilet facilities (L) and sign outside (R) on Schuylkill River Trail, Philadelphia

In 2010, the SRDC in combination with the Philadelphia Parks and Recreation Department installed a composting toilet along the River Trail. Once again, the primary driver for the toilet was the absence of a sewer line to connect to; however, like the other installations, the SRDC views the toilet as in keeping with their "environmental mission." Indeed, the toilet comes equipped with signs both inside and outside explaining how it should be used, how it works, and why it is important to conserve water (Figure 25, Figure 26).

The toilet, built and designed by Al White of Bio-Sun Systems, was constructed to absorb all usage for 15 years without the need for disposal. Josh Nims who is employed by the SRDC explained that with the exception of the severe flooding that occurred in early fall 2011, the facilities have required no special maintenance (personal communication, November 29, 2011).

The piles must be kept safe from inundating water. When the sides of the river banks rose during the 2011 floods, the storage facility underneath the toilets was penetrated and, according to Mr. Nims, the piles began bubbling and oozing and stinking (personal communication, November 29, 2011). It is possible that the cause for the sight and smell were the aerobic bacteria, which do not perform well when they suffer from lack of oxygen after being drowned in liquid. Though the floods were severe, they are not particularly unprecedented.


This Facility Is Equipped With An

Environmental Toilet

• NO FLUSH • NO CHEMICALS • NO SEWER

This toilet system recycles human waste into a clean reusable topsoil.

Figure 26: Interior of the women's composting toilet facility along the Schuylkill River Trail, Philadelphia

8.2 Potential alternative technologies

The previous chapter described the degree to which publically available sustainable sanitation technologies have been incorporate in Philadelphia. To compare the situation in Philadelphia to other metropolitan areas, a literature review of implemented sustainable sanitation technologies was conducted. Eliminated from the literature review were systems in developing countries, whose economic, social, and political contexts differ too dramatically to merit consideration for comparison. The literature review results determined that some variety of sustainable sanitation technology has been incorporated in the following locations: New York City, USA; Sneek, Netherlands; Solar City in Linz, Austria (Hochedliner, et al., 2008); Hamburg, Germany (Rauschning, Berger, Ebeling, & Schöpe, 2009); Eschborn, Germany (Winker & Saadoun, 2011); Lamberstmühle, Germany, Lübeck-Flintenbreite, Germany; Svanholm Community, Denmark, and Sund, Finland (Langergraber, 2005), though this list is not exhaustive. The exact components of each system differ, but the common features adhere to the definition of sustainable sanitation. The scale of decentralization varies between community level and the level of individual buildings, so an example of both is presented below.

8.2.1 Solaire apartments, NYC

Located along the Hudson River on Manhattan Island, the Solaire apartment houses a membrane biological treatment system in its basement with the capacity to treat and recycle 95 cubic meters per day of wastewater from the apartments. The reclaimed wastewater is then used for irrigating the rooftop gardens, to flush the toilets, and to cool the building. Any excess wastewater and biosolid material are sent to the North River Wastewater Treatment plant in New York City and used for biogas and energy production (Perry L. McCarty, et al., 2011).

The building, which was completed in 2003, is 33,160 cubic meters in area and has achieved a platinum LEED rating, the highest level of LEED certification. When it was first unveiled, it was considered the "greenest high rise residential condo in the United States" (U.S. Green Building Council, 2008a). Through its design, the building uses 55 percent less potable water than similarly sized multiunit residential complexes.

The costs of the project totaled $135.5 million, of which $20 million went to purchase the land (U.S. Green Building Council, 2008a). The financing structure used "an innovative approach including public-sector participation that was subsequently replaced by economic incentive Liberty Bonds issued by the State of New York Housing Finance Authority" (U.S. Green Building Council, 2008a). These government bonds were further subsidized by additional grants from the New York State Energy Research and Development Authority and the U.S. Department of Energy. The remaining financing was provided by permanent credit enhancements provided through a private bank. Having met the requirements of the New York State Green Buildings Tax Credit, the Solaire also received tax credits on the order of $2.8 million over a span of five years (U.S. Green Building Council, 2008a). The cost of the wastewater treatment system was approximately $1 million, though "payback for this system cannot be readily calculated" (U.S. Green Building Council, 2008a). Rental prices for an apartment in the luxury building range from $4,875 for a one-bedroom to $9,500 for a three-bedroom space ("The Solaire,").

Upon reflection of the Solaire project, the U.S. Green Building Council drafted a list of lessons learned. Two of the lessons on this list with broader implication for replication of this system elsewhere are (1) "local labor practice and construction methodology are as critical to sustainable design implementation as proper design and available technology" and (2) "analysis of building performance for various submissions relied heavily on performance relative to benchmarks. Very little benchmark data exists for high-rise residential buildings in New York City, and building standards vary widely compared to commercial structures" (U.S. Green Building Council, 2008b).

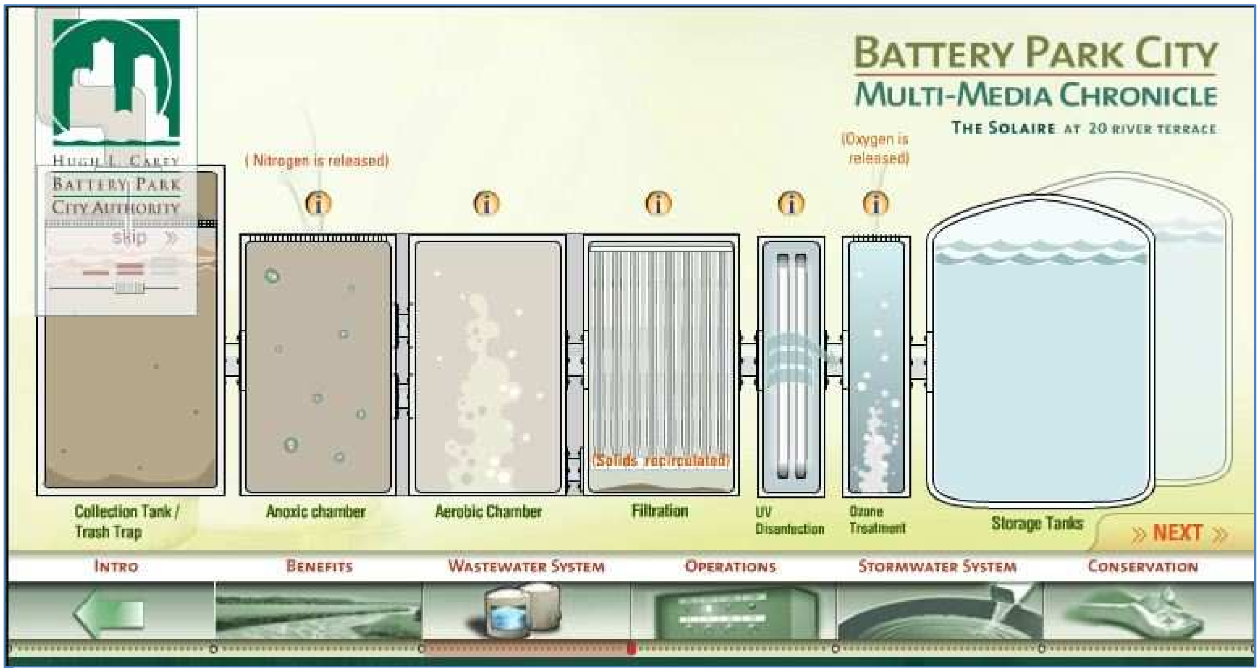


Figure 27: Diagram of Solaire in-house wastewater treatment system (*www.thesolaire.com*)

In the wastewater system, blackwater (urine and fecal matter) is collected and purified through a combination of innovative and conventional technologies as shown in Figure 27. The blackwater is accumulated in a collection tank before moving through anoxic/anaerobic biological treatment to remove biodegradable nutrients and organics. The anoxic/anaerobic treatment removes both nitrogen and phosphorous from the wastewater while simultaneously producing methane and converting nitrogen to nitrogen gas. The addition of ZeeWeed ultrafiltration membranes within the bioreactor eliminates the need to settle solids, which in turn cuts down on the size needed for the treatment tanks. The wastewater is pulled via permeate pumps through membrane filters, each of which are comprised of billions of microscopic pores. These pores act as physical barriers, blocking suspended solids, viruses, and bacteria from passing through. Finally, the wastewater undergoes both UV and ozone treatment, the first as a final disinfectant and the second to ensure total removal of color and odor. The treated wastewater is then stored in tanks which serve as reservoirs which supply the building with potable water for non-potable purposes. The typical water quality for the final treated effluent is shown in Table 4. In addition to the wastewater treatment capabilities, the building captures and stores up to 45 cubic meters of runoff from the roof, water which is also used to irrigate the rooftop gardens. The Solaire apartment building design is a good example of the type of decentralized sustainable sanitation that is potentially implementable in the United States. As Novotny et al. (2010) note, however, "the resource recovery is still incomplete in comparison to the current eco-city developments outside of the United States" (p. 297).

Table 4: Water quality of raw and treated water, Solaire apartment building, New York City (*Novotny et. al, 2010*)

	Raw Water	Treated Water
BOD (mg/L)	230	<2
TP (mg/L)	10	<1
TN (mg/L)	45	<3

8.2.2 Sneek, the Netherlands

In 2006, a pilot project consisting of 32 houses was undertaken in Sneek, a small village in the northern province of Friesland in the Netherlands. Vacuum toilets were installed in the houses along with source separation technology for the black- and greywater streams (**Error! Reference source not found.**). The blackwater stream is treated first through anaerobic digestion to recover energy before undergoing treatment to precipitate struvite to recover nitrogen and phosphorous. According to Reinhard & Folmer (2009), concentration of the black water stream from the Sneek community is 400 to 800 times greater than the wastewater entering wastewater treatment facilities (Reinhard & Folmer, 2009).

The project was facilitated by support provided jointly by industry, local government entities, including the water board that governs the area Wetterskip Fryslân, and Wageningen University. The development of the project in Sneek was not without its regulatory difficulties. The project experienced initial delays, as the vacuum flush toilets incorporated in the eco-community were not permitted to be connected to the water supply lines (Reinhard & Folmer, 2009). Ultimately, the regulations were altered to accommodate the pilot project. One potential reason for the support provided for the Sneek project is the increasingly stringent guidelines for water quality outlined in the European Union's Water Framework Directive.

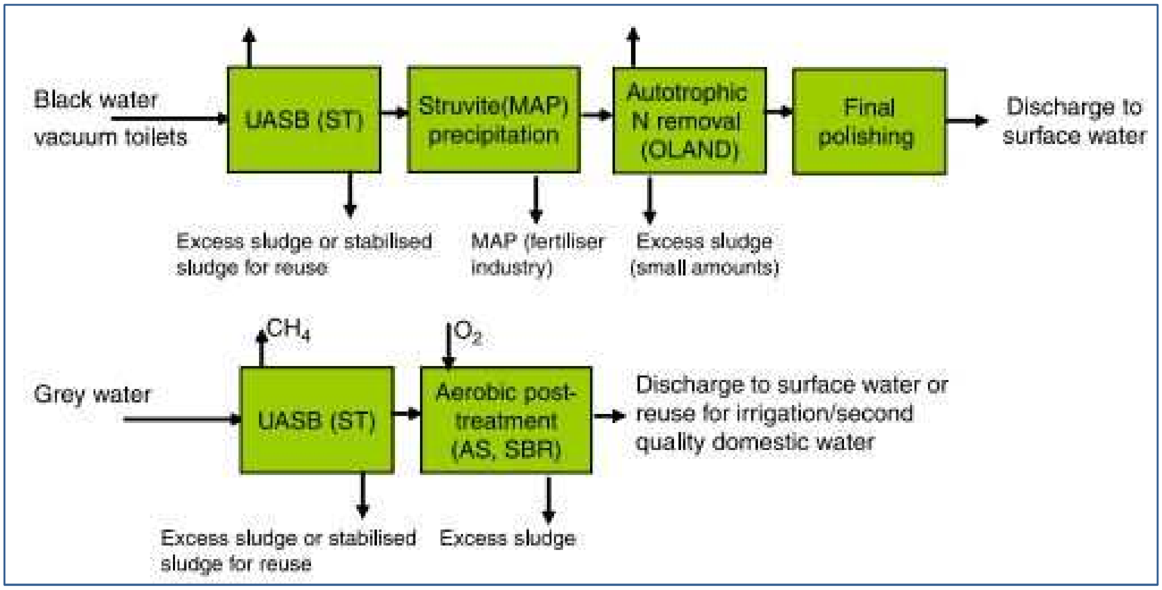


Figure 28: Diagram of treatment process for pilot project, Sneek, Netherlands (Zeeman et al., 2008)

According to Zeeman et al. (2008), when compared to conventional sanitation in the Netherlands, the Sneek project results in an energy savings of 200MJ per person per year. The calculations include the energy required for vacuum collection, transport, and anaerobic treatment process of black water, kitchen waste, and greywater. Additionally, the system produces 90 liters of potentially reusable water and recovers 0.14kg of phosphorus per person per year (Zeeman, et al., 2008).

Source separation technology attempts to make nutrient capture from wastewater economically feasible by concentrating the material. In domestic wastewater, approximately three-quarters of phosphorus is contained in urine and feces. The contribution of toilets to total household wastewater production hovers around 30 percent on average, though it can be as low as 3 percent in vacuum toilet systems. Separate treatment of these streams can allow for concentrations of phosphorus on the order of 60 $mg \cdot l^{-1}$ to 200 $mg \cdot l^{-1}$, thereby increasing the efficiency of phosphorus recovery (Reinhard & Folmer, 2009).

8.3 Obstacles, difficulties, and drawbacks

These case studies highlight the possibilities for sustainable sanitation at two levels of decentralization. They also bring to the fore the challenges that implementing these technologies pose. Despite minor differences in municipal regulation, given the proximity of New York City to Philadelphia, the possibility for technology transfer seems high. One possible deterrent is the cost. Innovative technologies and systems, such as those employed in both case studies, usually come with hefty price tags. The increased costs are usually due to limited or custom-made materials and skilled labor, additional effort to ensure compliance with regulations, and the costs of refining and optimizing a technology under development. In order to overcome the obstacles that research and development costs erect, it is essential that pilot projects find both regulatory and financial support from the municipal, state, and/or federal governments. Selling sustainability as a funding priority can be a challenge for government officials, however. It can be difficult to argue effectively for sustainable systems investments in the face of failing schools, homelessness, hunger, poverty, crime and any of the multitude of other responsibilities that a municipality must shoulder. For Philadelphia, a city with severely constrained finances in a time of globally constrained finances, the matter of costs takes on added importance.

Furthermore, sustainable sanitation technologies are somewhat risky in addition to being costly, since they are relatively new and the various types and systems are still being investigated for efficiency and applicability. Support for centralized systems usually comes from professionals in the public health sphere, as well, who raise concerns about the potential for disease outbreaks as a result of improperly treated waste in alternative systems. The decentralized systems may present a challenge to the consumer as they may deviate from what the Western world considers the sanitary "norm." This deviation may translate into a self-selecting consumer market, limiting broad-scale application, and keeping system prices high. Furthermore, in a city like Philadelphia where average rental prices hover around $1,300 per month, the staggering monthly rental cost of a building such as the Solaire could be difficult to market. Philadelphia-specific research into the economic realities of the belief that centralization yields economies of scale would be required as well.

In order to motivate the transition, sufficient drivers must be in place. Currently, the drivers motivating the PWD are compliance with the CWA and reducing the PWD's reliance on external energy sources (Chris Crockett, personal communication, March 8, 2012). Given the developments currently underway in Philadelphia, the conventional centralized system will likely be able to accomplish these goals within the time frame set out in the *Green City Clean Waters* plan. Until the cultural and political paradigm shifts significantly enough to establish the proper drivers, the concept of sustainable, decentralized sanitation will remain an interesting, but primarily academic, idea.

Some point to the LEED rating system as a potential driver of sustainable technology implementation as the LEED brand capitalizes on the cultural currency of "living green", a lifestyle that often comes with a premium. In some instances, this has proven successful, but the LEED system focuses primarily on energy and energy savings. As some critics note, the standards "are not a priori related to natural resources, and the value (total number of points) for natural resource protection and water resources conservation is relatively small; only about 15% of the points are credited for reducing water use and for potential contribution to improving the integrity of waters and natural resources" (Novotny et al., 2010, p. 117). Even with an improvement in LEED indicators, a voluntary program for sustainable design and construction would likely not be in itself a sufficient driver to alter the operations of a government utility. This is especially true for a utility like PWD which must remain fiscally accountable to a public that is unhappy to see prices go up and a City Council that is unwilling to legislate for higher tariffs. Lastly, Philadelphia is a major metropolitan city and the PWD is responsible for the waste and water of millions of customers. Legacy systems such as these are similar to large ocean vessels: once they are set on a course, it is difficult to alter it, and even should they change direction, the process takes time.

9 Current sanitation and sustainability paradigm in Philadelphia

In order to characterize the sanitation paradigm in Philadelphia and how it is viewed by those who operate within it, a SciVerse SCOPUS analysis of published articles is conducted as well as a survey of relevant actors in the wastewater field.

9.1 SciVerse SCOPUS analysis

The SciVerse SCOPUS is the largest bibliographic database of abstracts and citations for research publications. Using the database as a tool, one can extrapolate based on keyword and institutional affiliation searches the extent to which a particular research institute or academic body takes part in and contributes to a global scientific discussion on a particular topic. This use of citations and output as an analytical mechanism falls under the burgeoning field of bibliometrics and has shown to be a useful comparative tool with a variety of applications (Bornmann, Leydesdorff, Walch-Solimena, & Ettl, 2011; López-Illescas, de Moya-Anegón, & Moed, 2008).

An analysis using several databases of world university rankings informed the decision to compare the University of Pennsylvania (UPenn) and Drexel University in Philadelphia, The Swiss Federal Institute of Technology (ETH Zürich), University College London (UCL), and Darmstadt Technical University (Technische Universität Darmstadt) and Dresden Technical

University (Technische Universität Dresden) in Germany (Table 17, Table 18, Table 19). UPenn is compared to ETH Zürich and University College London. Drexel University is compared to Technische Universität Darmstadt and Technische Universität Dresden.

Since records prior to 1996 and 2012 are incomplete, the range is set between 1996 and 2011. Those fifteen years are divided into two relatively equal time periods, the first from 1996-2004 and the second from 2005-2011. First, a baseline number of total articles published for 1996-2011 was conducted for each university. This process was then repeated to determine the total number of articles published by institution on a number of topic relevant to this research between 1994-2004 and then again from 2005-2011 as a measure of relative output.

Once a baseline was established, a keyword search was combined with the affiliation search. Searches for the following keywords and keyword combinations were conducted: water; wastewater/"waste water"; sustainability/sustainable; stormwater/"storm water"; sanitation; sewage/sewerage/sewer; and ecological sanitation/ecosan. These keywords were then combined with an additional keyword to search within them for articles pertaining to sustainability. The categories for this second search became: sustainable/sustainability and water; sustainable/sustainability and wastewater/"waste water"; sustainable/sustainability and stormwater/"storm water"; sustainable/sustainability and sanitation; sustainable/ sustainability and sewage/sewerage/sewer[3]. Ecological sanitation/ecosan was not combined with keywords for sustainability because the term implies sustainability and returned only one hit across all six universities. The one article with ecosan or ecological sanitation as a keyword was affiliated with ETH Zürich but had no citations. The keyword searches were conducted for all years between 1996 and 2011 and then subdivided into the two designated time periods. The process of choosing which keywords to include in the search was informed by the literature review on sustainable sanitation to isolate which specific keywords were most likely to be associated with articles pertaining to water and wastewater research and, within that research base, how many of those articles included a sustainability focus. The results are shown in the tables below.

The results offer several interesting insights. UPenn and UCL produced comparably large numbers of publications between 1996-2011, while articles affiliated with ETH Zürich totaled slightly more than half the output of UCL. In the comparison between UPenn, ETH Zürich, and University College London, it is clear that across all keyword categories UPenn often returns the fewest hits, both in publications and impact as a measure of number of citations. In every category but sanitation, ETH Zürich published more articles and influenced a larger audience than UPenn, often by a factor of two or more. Not only has ETH Zürich published more articles in practically every category than UPenn, but those articles also constitute an almost doubly large percentage of ETH Zürich's research interest.

The searches for stormwater and sanitation produced relatively few hits across all three universities. Neither UPenn nor UCL had any publications with stormwater as a keyword. ETH Zürich had only eight total hits with slightly more published during the second time period. These eight publications had been cited nearly one hundred times, however. All three universities had publication hits for keyword sanitation, though relatively small output compared to the other categories. UCL had the greatest number of sanitation publications with twenty-two and the largest impact at nearly 200 citations. Interestingly, although ETH Zürich

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[3] To ensure that all articles with the intended keywords were returned, variations of a term or word were sometimes included.

generally produced the largest number of publications in every other category, it had the smallest number of publications with sanitation keywords and a substantially smaller citation impact. UPenn had eight publications affiliated with sanitation and 71 total citations. A closer inspection of the sanitation articles linked to UPenn revealed two studies on the number and characteristics of individuals using neighborhood parks (including their sanitary practices), one study on the social determinants of drinking water beliefs among a community in Guatemala, two studies focusing on hospitals and public health research, one article on child toilet training, and one on the sanitizing effects of desiccant-based cooling.

Table 5: Number of citations and articles by keyword for UPenn, ETH Zürich and UCL, 1996-2011 (SciVerse SCOPUS)

	Keyword	Total articles	water	wastewater/ "waste water"	sustainability/ sustainable	stormwater/ "storm water"	sanitation	sewage/ sewerage/ sewer
UPenn	**Articles**	59,438	733	12	38	0	8	6
	1996-2004	24,148	298	5	12	0	3	1
	2005-2011	35,290	435	7	26	0	5	5
	Citations	--	21,759	197	339	0	71	25
ETH Zürich	**Articles**	34,167	1,787	110	144	8	4	83
	1996-2004	13,455	462	31	23	3	1	32
	2005-2011	20,712	1,325	79	123	5	3	51
	Citations	--	34,914	2,677	902	98	5	1,744
UCL	**Articles**	60,837	1,447	33	132	0	22	29
	1996-2004	26,702	591	13	51	0	11	17
	2005-2011	34,135	856	20	81	0	11	12
	Citations	--	29,184	721	1,144	0	193	560

The most striking differences in output can be seen in the searches for water, wastewater, sustainability, and sewage. In these four categories, the output and influence of UPenn is one-half to one-fourteenth of what has been produced at ETH Zürich and University College London.

The SCOPUS SciVerse database shows an increase in total output for all universities between the two time periods. This increase is especially significant given that the first period between 1996-2004 is one year longer than the period between 2005-2011. This increase is possibly a result of increasing ability to incorporate citation data in real time due to technological advancements in addition to other trends in research, such as the growing number of journal. UPenn, ETH Zürich, and University College London increased total output by 9 percent, 11 percent, and 6 percent, respectively, between the two periods (Table 6). After adjusting for the percentage in total output, one can gauge the degree to which there is a relative increase of output in that category. This analysis shows no change in output in water at UPenn and even a slight decrease in wastewater research. By contrast, output for water increased 13 percent at ETH Zürich and 3 percent at University College London. ETH Zürich increase wastewater-keyworded output by 11 percent. UCL increased output in the wastewater category by 5 percent. For keyword sustainability, UPenn increased relative output 9 percent, ETH Zürich 24 percent, and UCL only 5 percent.

Table 6: Absolute and relative keyword output change between time periods for UPENN, ETH Zürich and UCL (1996-2004, 2005-2011)

	Total Output	water		wastewater/ "waste water"		sustainable/ sustainability		sewer/ sewerage/ sewage	
		Absolute change	Relative change	Absolute change	Relative change	Absolute change	Relative change	Absolute change	Relative change
UPenn	+9%	+9%	0%	+8%	-1 %	+18%	+9%	+33%	+24%
ETH Zürich	+11%	+24%	+13%	+22%	+11%	+35%	+24%	+12%	+1%
UCL	+6 %	+9%	+3%	+11%	+5%	+11%	+5%	-7%	-15%

With respect to sewage and sewerage, the story is slightly different. UCL actually decreased output between 2005 and 2011 by 15 percent, while UPenn increased output by almost 25 percent. The total number of sewage and sewerage articles affiliated with UPenn remains in the single digits, however, increasing from one published article in the first time period to 5 published articles in the second. ETH Zürich increased output in this category by only one percent, but produced an absolute number of articles almost triple that of UCL and more than 10 times UPenn. It is important to note, as well, that while UPenn increased absolute output in all categories except stormwater, the power of its output as measured by the citations is consistently the smallest.

Delving further into the results, Table 7 displays the results of the search to investigate what, if any, articles were returned when the initial keywords were combined with keyword sustainable or sustainability. No hits were returned for any of the three universities when the search terms for sustainability were combined with keywords stormwater or sanitation, the two categories that returned the fewest number of hits during the initial search. Once again, the search for articles with keyword water produced the greatest number of results across all three universities. ETH Zürich and UCL had a similar number of articles on water and sustainability at 11 and 12, respectively. UCL had a slightly larger impact at 121 citations compared to ETH Zürich's 100 citations. UPenn produced only two articles pertaining to water and sustainability, but they had a combined citation impact of 59. Of the UPenn articles affiliated with water and sustainability, one was a study of desalination technology in the Gulf Coast and had been cited 6 times. The other was a sensitivity analysis of nitrogen losses from dairy farms from 1997 with 53 citations.

The combination of wastewater and sustainability turned up zero results for UCL and ETH Zürich and only one for UPenn. Likewise, UPenn only had one hit when sewage and sewerage were combined with sustainability. Upon closer inspection, it was determined that it was the same article on desalination that had surfaced under both the sustainability and water and sustainability and wastewater searches. ETH Zürich had only three articles and eight citations in the sewage and sustainability category. Two of the articles affiliated with ETH Zürich were on renewable energy technology performance and life-cycle assessments. The third article was a study of regional mass flux balancing. UCL had no articles in this category, either. Overall, with the exception of the water and sustainability category, the results across all three universities and across all combinations of keywords and sustainability were almost negligibly small.

Table 7: Sustainability searches within water, wastewater, and sewage keyword searches for UPENN, ETH Zürich, and UCL (1996-2011)
(*SciVerse SCOPUS*)

Keyword		**water & sustainable/ sustainability**	**wastewater/ "waste water" & sustainable/ sustainability**	**sewage/sewerage/ sewer & sustainable/ sustainability**
UPenn	**Total Articles**	2	1	1
	1996-2004	1	0	0
	2005-2011	1	1	1
	Citations	59	6	6
ETH Zürich	**Total Articles**	11	0	3
	1996-2004	4	0	1
	2005-2011	7	0	2
	Citations	100	0	8
UCL	**Total Articles**	12	0	0
	1996-2004	3	0	0
	2005-2011	9	0	0
	Citations	121	0	0

Interestingly, the comparison between Drexel University and the comparably ranked German institutions yielded results that are more equitable. Though the German institutions had more publications on wastewater, and sewage, for the most part Drexel's absolute output by category was in keeping with Darmstadt and Dresden (Table 8). It is important to note that Drexel's total output was close to 10,000 articles, 60 percent larger than TU Darmstadt and 25 percent larger than TU Dresden. Therefore, though Drexel's absolute output may compare equally to the German institutions, the output as a percentage of the total output is greater among the international institutions. This same situation was described above between UPenn and ETH Zürich.

Table 8: Number of citations for total articles by keyword, Drexel, TU Darmstadt, TU Dresden (1996-2011) (*SciVerse SCOPUS*)

Keyword		Total	water	wastewater/ "waste water"	sustainability/ sustainable	stormwater/ "storm water"	sanitation	sewage/ sewerage/ sewer
Drexel	**Articles**	9,379	300	17	10	3	1	12
	1996-2004	2,802	112	3	0	0	0	5
	2005-2011	6,577	188	4	10	3	1	7
	Total Citation	--	4,507	98	66	4	4	102
TU Darmstadt	**Articles**	3,853	128	27	10	2	1	16
	1996-2004	813	20	5	0	0	0	1
	2005-2011	3,040	108	22	10	2	1	15
	Total Citation	--	1,123	69	41	12	5	39
TU Dresden	**Articles**	6,935	199	21	7	4	1	16
	1996-2004	2,630	56	3	1	0	0	3
	2005-2011	4,305	143	18	6	4	1	13
	Total Citation	--	1,997	189	15	14	6	176

The three hundred articles Drexel produced with the keyword water was more than twice the number produced by TU Darmstadt and one-third larger than TU Dresden. Drexel's water articles also dominated the citation sphere, laying claim to 4,500 citations compared to TU Dresden's almost 2,000 and TU Darmstadt's 1,123. Drexel produced a comparable number of articles across all categories except wastewater and sewage. TU Darmstadt produced almost 40 percent more articles than Drexel with wastewater as a keyword. However, despite a smaller total output, Drexel's citation record in wastewater trumps TU Darmstadt by almost 30 percent. TU Dresden's 21 articles with keyword wastewater have the largest impact, with 189 citations, more than double Drexel's and over 60 percent greater than TU Darmstadt. A similar result arose from the sustainability as keyword search. Though Drexel and TU Darmstadt both produced 10 articles, Drexel's influence was greater by almost 40 percent. Additionally, with respect to sewage and sewerage, although Drexel had the smallest number of output, the citation impact was substantially greater than TU Darmstadt, though Drexel's citations remaining significantly below those of TU Dresden. The results for sanitation yielded almost identical results. All three universities published one article in the second time period with a handful of citations. Drexel's record on stormwater is also comparable to the Germany universities with respect to total output. However, the impact of the three stormwater articles affiliated with Drexel is a fraction of the citations of TU Dresden and TU Darmstadt, though the impact of these universities remains relatively small at less than 15 citations each.

Looking at relative increases, once again stormwater and sanitation were eliminated from the comparison due to the small number of articles returned. Interestingly, all three universities had a few stormwater articles, all published during the second time period, compared to the higher ranked universities, two of which had no stormwater articles. The three lesser ranked universities all experienced dramatic growth in total output between the two time periods. Even TU Dresden, which had the lowest growth in total output, still increased article publication by 12 percent, a greater increase than the higher ranked universities. TU Darmstadt experienced the most remarkable growth, increasing article output by almost 30 percent. These increasing figures likely have a similar impetus as those driving increased output of the higher ranking universities. The reason for the difference in growth between the two tiers likely has something to do with the fact that the total output of the lower ranked institutions is a fraction of the higher ranked institutions so comparably small increases in absolute output will result in a higher relative output. It is possible that the lesser ranked universities are also responding to another driver that would explain the striking difference in total output between the lesser and higher ranking universities, but it is beyond the scope of this thesis to identify those potential drivers.

Table 9: Absolute and relative keyword output change between time periods for Drexel, TU Darmstadt, and TU Dresden

	Total Output	**water**		**wastewater/ "waste water"**		**sustainable/ sustainability**		**sewer/ sewerage/ sewage**	
		Absolute change	Relative change	Absolute change	Relative change	Absolute change	Relative change	Absolute change	Relative change
Drexel	+20%	+13%	-7%	+32%	+12%	+100%	+80%	+8%	-12%
TU Darmstadt	+29%	+34%	+5%	+31%	+2%	+100%	+71%	+44%	+15%
TU Dresden	+12%	+22%	+10%	+36%	+24%	+36%	+24%	+31%	+19%

Despite the relatively significant absolute increase in Drexel's output pertaining to water, once the output of the whole university had been accounted for, the results showed a negative relative change of 7 percent compared to positive changes of 5 and almost 10 percent from TU Darmstadt and TU Dresden, respectively. Similarly, with respect to sewage, Drexel's relative output decreased almost 12 percent over time. This figure starkly contrasts with the almost 15 percent increase in sewage articles from TU Darmstadt and 20 percent increases from TU Dresden. Drexel experienced a 100 percent increase in articles with keyword sustainability along with TU Darmstadt. Both Drexel and TU Darmstadt published ten articles with keyword sustainability and all of the articles were published between 2005 and 2011. TU Dresden also increased output of sustainability-related articles, increasing from one article between 1996 and 2004 to six articles between 2005 and 2011, though the relative increase calculated was only 24 percent. TU Dresden increased relative output of wastewater at exactly the same rate as sustainability articles, at 24 percent. This relative increase in wastewater keyword articles was greater than either TU Darmstadt, with an adjusted increase of only slightly over 2 percent, or Drexel, which increased relative output by over 12 percent between the two time periods.

Table 10: Sustainability searches within water, wastewater, and sewage keyword searches for Drexel, TU Darmstadt, and TU Dresden(1996-2011)
(*SciVerse SCOPUS*)

Keyword		**water & sustainable/ sustainability**	**wastewater/ "waste water" & sustainable/ sustainability**	**stormwater/ "storm water" & sustainable/ sustainability**	**sewage/sewerage/ sewer & sustainable/ sustainability**
Drexel	**Total Articles**	4	2	1	2
	1996-2004	0	0	0	0
	2005-2011	4	2	1	2
	Citations	10	1	0	1
TU Darmstadt	**Total Articles**	2	1	0	1
	1996-2004	0	0	0	0
	2005-2011	2	1	0	1
	Citations	1	1	0	0
TU Dresden	**Total Articles**	4	0	0	0
	1996-2004	1	0	0	0
	2005-2011	3	0	0	0
	Citations	14	0	0	0

The search for combinations of keywords and sustainability yielded similar results as those from the higher ranked universities, although there was a single hit on the combination of stormwater and sustainability published by Drexel during the second time period but the article has not been cited. No results were returned for sustainability and sanitation across all three universities, exactly as with the previous study of the higher ranked universities. TU Dresden only had articles published with the keyword combination water and sustainability with four articles in this category. These four had the largest comparative impact with four more citations than the four articles Drexel had published. Between Drexel and TU Darmstadt, both had very small outputs and impacts in the category of wastewater and sustainability. Overall, the results of the sustainability search were almost negligible, similar to the results of the higher ranked universities.

9.1.1 Discussion

The major findings from this analysis are that while both UPenn and Drexel are present in the global discussion on water and wastewater, their presence is comparably small in contrast to similarly ranked international institutions. Research in water and wastewater at UPenn even underwent a relative decrease while ETH Zürich increased output in these areas by over 10 percent. ETH Zürich had the largest input to the global conversation of all six surveyed universities, both as a function of number of articles published and citations across all categories. This finding was especially striking given that ETH Zürich had a total publication output close to half that of UPenn and UCL.

The question inevitably arises: why is UPenn not engaged in water and sanitation to the same extent as similarly ranked international schools? While UPenn is not strictly a technical school, it does boast a large and prestigious engineering school within the university. However, the results of the SciVerse SCOPUS analysis would indicate that as an institution that ranks among the best not only in the nation but also in the world, UPenn is not participating in the global academic discourse on water and sanitation that comparable universities are. Surely, the decision on behalf of UPenn's engineering school to eliminate its civil and environmental engineering program, the department in which infrastructure and infrastructure systems are usually taught and researched, plays some part.

By contrast, ETH Zürich is home to EAWAG, an institute that is among the world's best when it comes to water- and sanitation-related research. Specifically, two of EAWAG's three core research areas are water in urban areas and water contaminants. Likewise, UCL is home to the Bartlett Development Planning Unit, whose stated purpose is to "build the capacity of professionals and institutions to design and implement innovative, sustainable and inclusive strategies at the local, national and global levels, that enable those people who are generally excluded from decision-making by poverty or their social and cultural identity, to play a full and rewarding role in their own development"(Development Planning Unit, 2012). The Development Planning Unit has four research clusters, all of which speak to water and sanitation infrastructure and management on some level. The clusters are (1) environmental justice, urbanization and resilience; (2) urban transformations; (3) diversity, social complexity and planning intervention; and (4) state and market: government and policy for development. Research at EAWAG and the Development Planning Unit focuses on strategies and innovations for developing countries and countries in transition. UPenn is affiliated with a similar organization, the Philadelphia Global Water Initiative (PGWI), which defines itself as "a group of interested organizations and individuals committed to helping to meet the UN Millennium Development Goals for water/sanitation throughout the world" (Philadelphia Global Water Initiative, 2012). However, although PGWI is involved in projects and research pertaining to water and sanitation, it is not a research institution and generally serves in a supervisory, fundraising, or awareness-raising capacity.

While UPenn produced dramatically less than the institutions to which it was compared, Drexel's output is more similar to that of TU Darmstadt and TU Dresden. Like UPenn, it decreased relative output in two categories between the two time periods, water and sewage. Drexel dramatically increased output in wastewater and sustainability. However, given that total output at Drexel was significantly larger than either of the German institutions, it stands to reason that Drexel as an institution does not emphasize water and wastewater research to the same degree.

As the theoretical discussion of new institutionalism laid out, academic institutions, particularly large research universities, significantly influence the decision-making environment, both actively and passively. An example of active influence can be found in the Sneek case study. The collaboration between Wageningen University and others was an essential component of the project. Compared to other international universities of similar stature, UPenn could play a significant role in shaping the discussion on water, sanitation, and sustainability, both locally and abroad. Drexel, while on more equal footing with its international peers, has produced one-sixth of what UPenn has and simply cannot be the driving force that an internationally renowned institution like UPenn could be. PWD employees are themselves likely graduates of one of these two universities. If they have not been exposed to theories and practical examples of sustainable sanitation during their education, the extent to which they will be open to sustainable sanitation concepts and implementation remains questionable. The degree to which this influences the institutional arrangement of wastewater management and the options that are presented to the PWD is unknowable, but likely significant.

It is imperative, however, to highlight the weaknesses of this analysis. The data becomes increasingly unreliable at smaller numbers and an additional qualitative screening analysis would be necessary to improve the accuracy of the results. Using citations as a proxy for impact is problematic because citation numbers are not static over time, but rather increase in correlation to recent publications that invoke them. As with any purely quantitative analysis, there is also the risk that something is lost in translation. For example, the data cannot speak with complete accuracy to the research culture of an institution. Going forward, research should be conducted to investigate the potential correlation between highly ranked international universities, their bibliometric data with respect to water and wastewater, and the presence or absence of a research institution dedicated to third-world development, such as those at ETH Zürich and UCL. Additionally, a survey of the educational materials utilized at Drexel and UPenn could be conducted to assess the presence of sustainable sanitation concepts in relation to conventional sanitation technologies. Recommended further research would include the incorporation of qualitative research to validate or disprove the findings herein.

9.2 Survey analysis

The SCOPUS analysis provided insight into one aspect of the institutional environment in Philadelphia by characterizing the extent to which two of the major research universities support and produce research on water and wastewater. To characterize the greater institutional environment, a survey focusing on wastewater and sustainability was drafted and distributed to twenty-five members of the wastewater policy community in Philadelphia. Those who received the survey are employed at the PWD, Drexel or UPenn, the DRBC, CDM, a private consulting firm that works closely with PWD, urban farms with composting toilets, vendors of composting toilets, or the Natural Academy of Sciences in Philadelphia, which coordinates several working groups on sustainability and the urban environment.

The survey featured ten questions intended to reveal how those in the policy community perceived the concept of sustainability with respect to water and sanitation. The survey included additional questions on place of employment, field and year in which bachelor's degree was received, area of expertise, current position, and rank in the authority hierarchy as a function of the number of individuals for whom one is responsible. Of the twenty-five people who received the survey, thirteen responded. Of those who responded, six work at a college or university, four at a local government agency, two at a for-profit company, and one identified as self-employed. Table 11, Table 12 and Table 13 display these results.

Table 11 shows the definitions of sustainability given by the respondents as well as their response to the question of whether or not Philadelphia was sustainable according to their own definition. To facilitate the analysis, the major points of each definition were teased out and summarized using keywords, which are also listed in Table 11. Table 12 and Table 13 display the results from the follow-up questions to whether the city's wastewater system is sustainable. For those who responded "yes", Table 12 shows their responses to the question of when the system became sustainable. For those who answered "no", Table 13 gives their estimates for when the system could conceivably become sustainable. All of the respondents were then asked to list three strategies to achieve a sustainable wastewater system in Philadelphia and to indicate whether these strategies were currently being pursued.

Four respondents gave ambiguous answers to the question of whether Philadelphia's water and wastewater system was sustainable. Three respondents replied "not applicable/no opinion" and one respondent responded both "yes" and "no". These four explained the reasoning for their inability to give one definitive answer in various ways. One respondent, who works in academia, explained that sustainability is not a static concept. Another respondent believes that PWD's technical competence and skilled workforce make it sustainable, while the impact of financial constraints, specifically the impact of strong labor unions, undermine the system's sustainability. The latter of these two is a person of considerable influence at a for-profit private firm, having indicated that over 20 people report to him or her. Another respondent working at a local government agency who answered both "yes" and "no" gives as an example the centuries-long length of time that the physical infrastructure lasts as justification for why the system was sustainable. However, this person also acknowledges the "massive and expensive" inefficiencies that abound as an example of how the system is not sustainable and concluded by stating that with the proper technology and management structure the system could become sustainable. The last of these four, who works at a local government agency, echoes this sentiment, stating that while the system is not sustainable in its current form, through increasing research and investments in energy and nutrient recovery and less chemical intensive forms of treatment, PWD is on its way to becoming sustainable.

Of the remaining nine participants, four gave a definitive "yes" answer and five gave a definitive "no" answer. Three of the four who definitively answered "yes" work at a local college or university. This finding seems particularly surprising as one would expect those in academia to hold the most 'progressive' ideas and therefore the most likely to find the existing system unsustainable. Of these three academics, two of them have between one to five individuals reporting to them, indicating that at the least they have completed their PhD and are likely employed as professors or lecturers. These two academics point to the fact that the city's use of water does not exceed supply, although they cite the energy cost of using drinking water for waste disposal and the potential problems of political will for financing as caveats to their argument. The third academic respondent also nodded to the fact that it will take time to tell if PWD is on the path to sustainability, noting the green stormwater infrastructure and programs to increase stakeholder involvement as signals that in fact PWD is indeed on that path. The fourth respondent to reply in the affirmative works on stormwater in a local government agency and defined sustainability through the lens of stormwater management. Unsurprisingly then, this individual found the city's *Green City Clean Waters* approach to be sufficient proof that the city's water and wastewater system is sustainable.

Two of the five respondents who answered definitively in the negative are employed at a local college or university, while the other three identified as self-employed, employed by a local government entity, or employed at a for-profit company. With the exception of one respondent, all of these five point to the energy wasting nature of the current system as a reason why it is not sustainable. One participant, who works at a for-profit company, specifically identified centralization as the feature responsible for the wasted energy. Three respondents identified the absence of energy and water reuse and recovery as justification for their decision. Of these two, one individual employed at a local government agency identified nutrients and assets as additional recoverable and reusable elements and stated that the PWD is "working towards" sustainability. The participant who identified as self-employed and working in research and development in sewage implementation is one of these three, and he or she highlights the inefficiency of waste conversion in the conventional system. The third of the three respondents, who focuses on the need for reuse and recovery, is college or university employee with over twenty subordinates.

The keywords, which represent the essential elements of each individual's definition of sustainability, provide a clue to the differences between those who answered "yes" and those who answered "no" or who were unable to give definitive responses. Those who believe Philadelphia's water and wastewater system is sustainable showed similarities in their understanding of sustainability. Two of these four focus on sustainable stormwater infrastructure and management, positing that capturing rainwater and preventing it from entering the "city's overtaxed sewer system and possibly contributes to the CSO problem" in a way that incorporates the urban citizenry was proof of sustainability. The keywords of the other two participants who answer "yes" include over-withdrawal, water quantity, safe drinking water, adequate sanitation, and energy efficiency with direct reference to carbon emissions. No mention is made of energy, water, or nutrients reuse, or of the potential comparative advantages of decentralized systems. Even the participant who gave a split answer of both "yes" and "no" defines sustainability as a process that requires "technology update to treatment plants [for] upgrading pipes/valves/tanks." Essentially, these individuals are focusing only on one part of the wastewater issue—stormwater—or they are enumerating issues correlated with the fourth paradigm, i.e. the current paradigm, of wastewater management. Lodged within the fourth paradigm, they view the essential issues as ensuring adequate sanitation achieved via the current centralized system, a process curtailed only by the available quantity of water.

By contrast, with one exception, the keywords stemming from the sustainability definitions of those who do not believe Philadelphia's sanitation system is sustainable include resource recovery, water reuse, energy reduction, and nutrient reuse. These keywords are indicative of an understanding of sustainability that corresponds to the fifth paradigm outlined by Novotny et al. (2010). The fifth paradigm is the last paradigm of wastewater management and calls for developed countries to make the transition to water centric sustainable communities. One academic who defined sustainability as "the ability to provide for the (water) needs of man without impinging upon the provision of such needs and the quality of the natural environment for future generations" explained that Philadelphia does not meet this definition because "sustainability in this context implies a substantial amount of reuse and recovery." The one individual whose answers and keywords differ from the other four cites the need to come into compliance with existing regulations, singling out stormwater and combined sewer overflows, as well as the potential threat of natural gas exploration in the watershed.

Table 11: Survey responses showing definition of sustainability and classification of Philadelphia water/wastewater system as sustainable or unsustainable

Place of employment	Type of employment	Is the WW system in Philadelphia sustainable?	Definition of sustainability	Keywords
A college or university Responsible for 1-5	Combination Stormwater/ Sewage/ Drinking Water – Education	**YES** For the most part; but need to worry about the political will to finance, how to treat for low level pollutants, etc	Providing safe drinking water and adequate sanitation services for many years to come. This would include adequate funding for operations/ maintenance/ replacement, technical expertise, public involvement, It would also include an adequate supply of freshwater, optimizing energy use, continuous improvement in water and carbon footprint.	Safe drinking water, adequate sanitation, economically sustainable, technically sustainable, stakeholder involvement
A college or university Responsible for 1-5	Drinking Water – Education	**YES** Philly relies on renewable surface water so for part A above [Point A in definition of sustainability] we are in good shape. For the use of drinking quality water for waste removal may not be sustainable due to energy requirements.	a) Avoid depletion of water resources through over withdrawals b) Treat and supply drinking water in an energy-efficient, low carbon emission manner	Water resource over withdrawals, water quantity, energy efficiency, carbon emissions
A college or university Responsible for 0	Stormwater – Research	**YES** Philadelphia's wastewater system is on a path toward sustainability. The City's Green Stormwater Infrastructure approach is a city-wide attempt at managing stormwater where it lands, with the aim of improving the quality of our rivers and providing the ancillary benefits of Green Infrastructure to communities. PWD recognizes the need to do this in a way that involves multiple stakeholders and the City's public in the process, and has been attempting to do so. This approach has only recently begun, so time will tell if it is sustainable or not.	In an urban context, sustainable stormwater management involves capturing stormwater runoff before it enters the city's overtaxed sewer system and possibly contributes to the CSO problem, and doing so in a way that is inclusive of the values of multiple stakeholders and the urban citizenry	Stormwater, CSO, stakeholder involvement
A local government	Stormwater – Policy	**YES** The "Green City, Clean Waters" program	From a stormwater perspective, "sustainability" means treating rainfall	Pre-urban hydrological cycle,

agency Responsible for 5-10		relies on decentralized green stormwater management practices. This approach was adopted in part because a comprehensive triple bottom line analysis comparing a green approach to a more conventional approach illustrated that City residents would gain greater benefit from investing in greening. Furthermore, these sustainable stormwater practices are coupled with investments in stream restoration to ensure healthier aquatic habitats.	as a resource and developing systems that replicate natural hydrologic processes. Therefore, the use of decentralized green stormwater infrastructure practices thoughtfully integrated into the urban environment and designed to maximize economic, social and environmental benefits best illustrates a sustainable stormwater management program.	stormwater harvesting, decentralized stormwater infrastructure, triple bottom line
A for-profit company Responsible for 20+	Drinking Water & Sewage – Policy & Management	**YES** Quality employees/technologically competent **NO** Capital has been deferred due to financial constraints. Union workforce demands higher operating costs from customers then necessary.	Technology update to treatment plants upgrading pipes/valves/tanks - infrastructure alternate energy applications	Infrastructure, alternative energy
A college or university Responsible for 20+	Drinking Water – Education	**NO** I think sustainability in this context implies a substantial amount of reuse and recovery -- both energy and water.	The ability to provide for the (water) needs of man without impinging upon the provision of such needs and the quality of the natural environment for future generations	Environment, human needs, balance, future generations
A college or university Responsible for 0	Combination Stormwater/ Sewage/ Drinking Water- Education	**NO** Combined sewer overflows a problem. Stormwater runoff a problem. And drinking water quality is threatened by development in the Schuylkill watershed and natural gas drilling in the Delaware watershed.	Compliance with the swimmable/ fishable water quality standards of the US Clean Water Act and the standards of the US Safe Drinking Water Act. Stormwater runoff should match pre-development hydrology (retained and infiltrated on site as much as possible). Sewage should be treated to secondary or tertiary levels, and no Combined sewer overflows or separate sewer overflows.	Compliance, pre-urban hydrological cycle, CSO, secondary/tertiary treatment

Local government agency Responsible for 1-5	Sewage – Research	**NO** Not yet. It is working towards to it.	In wastewater treatment industry, the sustainability should be to recover resources while removing contaminants. The recoverable resources in a WWTP are nutrient, energy, water and asset.	Resource recovery, contaminants, nutrient recovery, energy recovery, water recovery, asset recovery
A for-profit company Responsible for 1-5	Combination with a focus on Resource Saving and Sustainability – Management	**NO** Too centralized appears to require a nonsustainable and not local "power" sources to run.	Ability to replenish the resources used with the least amount of impact on any ecosystem.	Resource recovery, environment
Other: Self-employed/ R&D Responsible for 1-5	Sewage – Implementation	**NO** Energy intensive, water wasting , ineffective & incomplete waste conversion	Extreme water conservation plus self sustaining/ self enhancing symbiotic waste treatment	Water conservation, energy reduction, water reduction, resource recovery
A college or university Responsible for 1-5	Drinking Water – Research	**NO OPINION/NOT APPLICABLE** Sustainability is not a static state. It requires institutions, policies and behavior to become "more sustainable", at least until we believe that we have reached the maximum accommodation between human and natural systems.	Planning, design, operations and maintenance to minimize environmental impact while providing critical drinking water for urban areas.	Environment, drinking water, urban
Local government agency Responsible for 5-10	Combination Stormwater/ Sewage/ Drinking Water-Management	**NO OPINION/NOT APPLICABLE** PWD is somewhat sustainable. In wastewater, PWD is optimizing the anaerobic digester gas production to offsets energy (natural gas) purchases for sludge drying and (by 2013 with the construction of cogeneration facilities) to offset electricity purchases. We are currently in the conceptual study stage only for possible algaculture for nutrient recovery. For drinking water, PWD is	For water treatment sustainability means minimizing electricity usage and replacing chemical addition with biological treatment. In wastewater, sustainability includes capturing the energy or nutrients in the wastewater stream and converting it to a useable product, or offsetting the need to purchase electricity.	Energy reduction, chemical treatment reduction, biological treatment, energy recovery, nutrient recovery

		performing feasibility studies for less chemical intensive processes to disinfect the water		
A local government agency Responsible for 1-5	Combination Stormwater/ Sewage/ Drinking Water-Implementation	**YES** Sewers last for 200+ years; water mains 100+ years. This is mostly due to the high standards required by PWD. This reduces replacement frequency. **NO** Inefficiencies abound in the PWD system, starting with distribution loss and ending with CSOs. The scope of the problem in massive and expensive. **NO OPINION/NOT APPLICABLE** Both. With the increase in technology for trenchless pipe solutions, 'green' stormwater infrastructure and management restructuring, PWD can become sustainable	Brief? 'Sustainability' is a very broad term. It means creating a system that can be perpetuated with minimal impacts - environmental, societal, and economic.	Environment, society, economic, viable into the future

The differences between those who answered "yes" to the question on the sustainability of Philadelphia's wastewater system and those who answered "no" are further underscored by questions that probe into a timeline of sustainability and each respondent's recommended strategies to achieve sustainability (Table 12). The first question asked those who do believe the wastewater system to be sustainable to identify the moment in time that the city became sustainable. The second question, posed to those who did not find the current wastewater system sustainable, asked the respondents to identify how many years until Philadelphia could become sustainable (Table 13). Of the thirteen respondents, one abstained from answering either of these questions. This individual defined sustainability as a moving target that requires "institutions, policies and behavior to become 'more sustainable'" which may explain the hesitation on his or her behalf to assign a time stamp to sustainability. Two participants, who answer both "yes" *and* "no" or "yes" *and* "no" *and* "not applicable" to the question of whether Philadelphia's wastewater system is sustainable, gave responses to both questions on this topic.

The respondents who answered "yes" to the question pertaining to the sustainability of the wastewater system fell into two general categories based on their responses. Either they identified events early in the development of the current system, or they identified the most recent developments as the turning point of sustainability. The first category of respondents pinpointed the beginning of sustainability as two crucial developments in the early evolution of the current system: systematic water distribution, which began in the early 19th Century, and filtering and chlorination treatment, which came a century later. However, the two individuals who fell into this category have dramatically divergent viewpoints on the strategies for sustainability. In fact, the individual who identified the advent of disinfection as the turning point of sustainability listed three strategies for sustainability that more closely correspond to those given by the individuals who did not find the current system sustainable. Those strategies, including decentralized disinfection using renewable energy, demand management using dry sanitation, and ensuring a socially equitable rate structure, move beyond the fourth wastewater management paradigm into the fifth. The respondent correctly indicated that, with the exception of efforts to ensure equitable access, these strategies are currently not being pursued in Philadelphia. The strategies of the other individual in this category differ substantially and include monitoring and treating for low-level pollutants, increasing energy efficiency, and reinvesting in the centralized system, all solutions that the respondent indicates the city is currently pursuing and all of which are rooted firmly in a fourth paradigm perspective of sustainability.

The other four respondents who answered "yes" fell into the category in which the most recent developments were identified as the turning point in the sustainability timeline. Together, these four respondents emphasized the city's *Green City Clean Waters* plan, the green stormwater infrastructure that the plan lays out, and the integrated management approach that began in 1999 with the creation of the Office of Watersheds. Two of these four acknowledged that becoming sustainable is not a discrete event, but rather a transition that occurs over time. Both respondents listed green stormwater infrastructure as a strategy to achieving sustainability. From there, the strategies of these two diverged. The individual employed in academia listed water conservation methods and "alternative wastewater management efforts", without further clarification, as strategies to achieve sustainability and indicated that the city is not currently pursuing either of these two. The other individual, an employee at a local government agency, was more confident, giving a precise date at which the city became sustainable, and listing three strategies to achieving sustainability, all of which he or she indicates the city is currently pursuing.

The other two respondents who identifed recent developments as the turning point approach the question from a technical or financial perspective. As the turning point for sustainability, one respondent pointed to the $1 billion dollar investment in green infrastructure, while the other asserted that, "PWD has always been more 'sustainable' in its requirements for using top-grade materials and workmanship to reduce system failures." Their strategies for achieving sustainability follow in this vein, focusing on methods to improve the existing infrastructure by either ensuring the availability of capital, reducing costs, or increasing efficiency.

Table 12: When Philadelphia's water/wastewater system became sustainable and respondent strategies to achieve sustainability

Place of employment	Is the WW system in Philadelphia sustainable?	Moment in time that Philadelphia became sustainable	Strategies for achieving sustainability
A college or university Responsible for 1-5	YES	When the city began filtering and chlorinating its water supply.	1. On site generation of disinfectants with renewable energy – I don't believe they do this 2. Promotion of dry sanitation to reduce demand – they are not currently pursuing this. 3. Implement a rate structure that allows low-income households access to a sufficient amount of basic needs at a low cost. I do not know the rate structure in detail but suspect an effort is made to do this.
A college or university Responsible for 1-5	YES	This is a continuing process 1812 when water was first systematically distributed, early 1900 when disinfection started, 1970s when treatment plants were upgraded, etc	1. Systematic upgrading of the infrastructure; yes, City is pursuing, at least to some degree 2. Monitoring and treating for low level pollutants; yes, they are monitoring 3. Address how to be more energy efficient
A college or university Responsible for 0	YES	I would not say it is currently sustainable as a city-wide Green Stormwater Infrastructure approach to stormwater management has only recently begun...and it is still being figured out. I would say the City started on its path to sustainability a little bit when the Office of Watersheds was formed and then more when the Long Term Control Plan Update (Green City, Clean Waters) was released in 2009.	1. City-wide Green Stormwater Infrastructure. Yes. 2. City-wide water conservation efforts. No. 3. City-wide alternative wastewater management efforts. No.
A local government agency Responsible for 5-10	YES	Officially June 1, 2011 with the formal adoption by PA DEP of "Green City, Clean Waters." However, becoming "sustainable" does not occur at one particular point in time. A major turning point for Philadelphia was the establishment of the Office of Watersheds in 1999, bringing together	1. Green Stormwater Infrastructure (currently pursuing strategy) 2. Energy Efficiency and Alternative Energy (currently pursuing strategy) 3. Public-Private Partnerships (currently pursuing strategy)

		separate regulatory programs (stormwater, drinking water, combined sewer overflows) under the umbrella of watersheds and beginning integrated watershed-wide planning accounting for the full range of water resource issues.	
A local government agency* Responsible for 1-5	YES, NO, and NO OPINON/ NOT APPLICABLE	PWD has always been more 'sustainable' in its requirements for using top-grade materials and workmanship to reduce system failures.	1. Personnel management restructuring, to reduce operational costs. 2. Implementation of 'green' infrastructure for stormwater management (and possibly treatment as well). 3. Utilization of trenchless technologies in maintaining and renewing existing infrastructure and creating system efficiency.
A for-profit company* Responsible for 20+	YES and NO	Stormwater mgt ($1Billion) plans to address CSO's	1. More alternate energy 2. Higher rates to provide capital for plant upgrades and infrastructure replacement 3. Trim costs to moderate rates to be able to make capital improvements affordable

**Indicates respondent answered YES or YES and NO to question of whether Philadelphia's wastewater system was sustainable and provided answers for question 8 and question 9.*

Eight participants responded to the second question pertaining to the sustainability timeline. The second question asked them to identify when the wastewater system in Philadelphia could become sustainable and gave them the option to select either five, ten, fifteen, or twenty years from now (Table 13). The majority of respondents chose to select either fifteen years from now or twenty years from now as an answer. One individual ticked the ten years from now box and another participant, refusing to give a time in years, stated that it would take "an extended period of time with No "Power" to run the treatment plant(s) for both Schuylkill punch production and sewage."

For the most part, the strategies to achieve sustainability offered by the individuals in this group focused more on resource capture and reuse, and were more indicative of ideas in line with the fifth wastewater paradigm than the respondents were in the last category. With the exception of one self-employed individual, all of the respondents who gave a fifteen- to twenty-year time horizon work either in academia or in a local government entity. The two academics who responded to this question, both of whom selected twenty years as the timeline to achieving sustainability, indicated several strategies to achieve sustainability that the city was not currently pursuing. These strategies ranged from more holistic watershed protection, particularly stream restoration and land preservation in the watershed, to systematic improvements, such as decentralized non-potable water reclamation and stormwater reuse in addition to retention. The academics also noted two strategies that the city was currently pursuing, though to varying degrees: the green stormwater infrastructure installation and energy and resource recovery from wastewater.

The other participant who listed twenty years as the timeframe for sustainability works in a local government agency and had checked "no opinion/not applicable" to the question of whether he or she considered Philadelphia's wastewater system to be sustainable. As an explanation, this individual states that, "For a public utility, changing...treatment processes is very capital intensive. We can implement new projects with time to push us closer to sustainability, but it will be many years before we become fully sustainable." This individual then outlined three strategies to achieve sustainability, all of which had the ethos of the fifth paradigm but replete with the centralized structure inherent to the fourth. Instead of breaking with the centralized structure, he or she outlined strategies to optimize it, including increasing the energy capture in waste products, improving reuse of sludge for agriculture, and the potential of algaculture. All of these strategies are in the early phases of research and development or implementation in Philadelphia.

Of the three individuals who responded that the wastewater system in Philadelphia was approximately fifteen years from being sustainable, one person had provided an answer to this question as well as the previous question on the subject of the historical moment of time when the system became sustainable. However, this individual refrained from identifying a precise moment in history, but rather gave a comparative response stating that the PWD has always been "more sustainable" in its efforts to reduce system failures. Again, this individual feels that sustainability is an evolving transition, rather than a distinct event, and whose prescriptions for achieving sustainability concentrate on increasing efficiency in the current system. The other two strongly emphasized resource recovery and reuse—specifically heat, power, nutrients, and assets—and decentralized dry sanitation technologies under the heading "zero sewage". The individual whose recommended strategies focused on encouraging and, ultimately, mandating conversion to "zero sewage" made the prediction that sustainability could be achieved in wastewater in fifteen years only "if there is complete public/political will."

The final two respondents both identified as employees of private for-profit firms. An individual who gave a ten-year time horizon to achieving sustainability in Philadelphia had also answered the previous question, citing the city's billion-dollar investment in green stormwater infrastructure as the turning point on the path to sustainability and focusing on optimizing the current system as the necessary strategies to continue on this trajectory.

Table 13: When Philadelphia will become sustainable and respondent strategies for sustainability

Place of employment	Is the WW system in Philadelphia sustainable	Timeline for sustainability	Comments	Strategies for sustainability
A college or university Responsible for 20+	NO	20 years from now	--	1. Non potable water reclamation from large buildings and dense neighborhoods 2. Energy and resource recovery from wastewater 3. Stormwater recovery for non potable uses (not just retention)
A college or university Responsible for 0	NO	20 years from now	--	1. Green infrastructure to control stormwater runoff – yes, currently pursuing 2. Restoration of urban streams – no 3. Land preservation in the Schuylkill watershed (like New York City), no
A local government agency Responsible for 5-10	NO OPINON/ NOT APPLICABLE	20 years from now	For a public utility, changing...treatment processes is very capital intensive. We can implement new projects with time to push us closer to sustainability, but it will be many years before we become fully sustainable, as defined in question 7.	1. Cogeneration of electricity/heat recovery of digester gas – under contract, construction should commence spring 2012 2. Optimize waste sludge for agriculture land application – we have been doing for years, but have now (March 2012) improved to a class A product 3. Algae farming for biofuel or other high value product production – currently working with a university but only in very initial research stages
A local government agency* Responsible for 1-5	YES and NO and NO OPINON/ NOT APPLICABLE	15 years from now	--	1. Personnel management restructuring, to reduce operational costs. 2. Implementation of 'green' infrastructure for stormwater management (and possibly treatment as well). 3. Utilization of trenchless technologies in

				maintaining and renewing existing infrastructure and creating system efficiency.
A local government agency Responsible for 1-5	NO	15 years from now	--	1. Recovery and reuse nutrients in the wastewater stream 2. Heat and power recovery 3. Asset recovery in those WWTPs
Self-employed (R&D) Responsible for 1-5	NO	15 years from now	Only if there is complete public/political will	1. Deploy "Zero Sewage" in all new construction and renovation 2. Employ $ incentives for converting to "Zero Sewage" such as water/sewer rate reductions 3. Mandate conversions to "Zero Sewage"
A for-profit company* Responsible for 20+	YES and NO	10 years from now	When rates go up and costs go down	1. More alternate energy 2. Higher rates to provide capital for plant upgrades and infrastructure replacement 3. Trim costs to moderate rates to be able to make capital improvements affordable
A for-profit company Responsible for 1-5	NO	See comments	It may take an extended period of time with No "Power" to run the treatment plant(s) for both Schuylkill punch production and sewage	1. Plan for sustainable alternate power (solar, wind, hydro, local methane) use when power goes down 2. Recognized what part of the process can reclaim/create energy or potable water 3. Encourage local sewage and water management, from composting toilets/systems to offering serious water conservation tools (low flow shower heads, dual flush toilets, point of use water shut-off valves, etc...)

**Indicates respondent answered YES or YES and NO to question of whether Philadelphia's wastewater system was sustainable and provided answers for question 8 and question 9.*

9.2.1 Discussion

This survey analysis provides further insight into the location of Philadelphia's wastewater policy community with respect to the paradigm structure outlined in the theoretical framework. There was a considerable degree of agreement between certain individuals. For example, many of the respondents acknowledged the positive impact of the city's green stormwater infrastructure on the city's long-term sustainability. There was a surprising range of diversity between some of the answers. The analysis shows that the mentality of the fourth paradigm remains embedded within academia, local government, and the private sector, with respondents from each of these institutions indicating a commitment to the conventional centralized system, albeit with improvements, particularly with respect to energy production. Chris Crockett, the PWD Deputy Commissioner of Planning and Environmental Services, clearly stated that increased energy production and ultimate energy independence was a goal of the PWD moving forward, a position that this survey suggests is supported by others in the policy community (personal communication, March 8, 2011). The survey also demonstrated that sustainable sanitation themes such as resource recovery and reuse had penetrated the decision-making environment to some degree. The survey revealed that there are those who view a sustainable wastewater system to be something radically different from that which exists at present.

The methodology employed to arrive at these conclusions is not without weakness, however. The sample size, while not insignificant, is still too small to be able to make broad characterizations with accuracy. Additionally, the participants are not representative of all members of the institutional environment outlined in the theoretical framework. Specifically lacking from this analysis are the voices of the network of global experts and the public consumers. The works also suffers from the same issues that plague any work in which surveys are completed on a voluntary basis only. Those who feel most strongly about a given topic are those most likely to take the time to respond, leading to potentially skewed answers. The sample is also not representative, as the numbers of respondents for each node of the decision-making community are not equal, but instead heavily biased in favor of academic institutions and local government entities. A larger, more representative sample size followed up with roundtable discussions or interviews would improve the accuracy of these results.

10 Final discussion and conclusions

The problem facing Philadelphia is well captured by Lüthi et al., "In the developed world, the challenge is to initiate a transition from disposal oriented, water-based infrastructure regimes towards more sustainable, reuse oriented, and productive sanitation regimes (Lüthi, et al., 2009)." By this measure, the current wastewater management scheme in Philadelphia is not sustainable, although the city has made significant strides in certain regards. The *Green City Clean Waters* plan will likely reduce the amount of stormwater funneled through the combined sewer network, reducing the amount of untreated wastewater spills into the rivers and streams. The plan will accomplish this goal partly through the large-scale introduction of decentralized stormwater systems. Over the next several years, the PWD will increase the amount of energy produced from wastewater, thereby harnessing some of the reuse potential. The upgraded BRC pelletizing system will ensure a larger amount of reused biosolids. All of these strategies are in keeping with the ethos of the water centric sustainable communities of the fifth wastewater paradigm.

However, the system continues to waste vast amounts of limited resources, including energy and water, does not adequately protect the environmental health of the surrounding surface water bodies and does not effectively recover the nutrients present in human waste. The captured stormwater will not be incorporated in the majority of households as an alternative source of non-potable water. The infrastructure dealing with water distribution and wastewater collection and treatment will remain centralized, and much of the phosphorus and nitrogen will continue to be discharged untreated into the nearby surface waters.

This research has demonstrated that the reason why Philadelphia's transition to a more sustainable wastewater system is so asymmetric is rooted in the historical evolution of its current system and a distinct lack of leadership in the policy community to promote sustainable sanitation. When alternative, dry-sanitation systems proved incapable of adequately disposing of Philadelphia's exploding volume of wastewater following the introduction of piped water, the decision to advocate, legislate, and institutionalize the culture of flushing was made. That decision gave rise to an enormous, complex, expensive infrastructure, which took both physical and psychological forms. Two hundred years later and that infrastructure has so embedded itself in the day-to-day practice of most citizens that alternatives are rarely, if ever considered, even among professionals.

In areas where alternative, sustainable sanitation systems are being implemented, the role of a supportive regulatory framework and strong academic institutions was found to be a vital component. In Philadelphia, the regulatory framework does not explicitly ban alternative forms of sanitation, but those in the policy-making community are also not advocating for its presence and so it has no substantial local presence. Part of the reason why the policy-making community does not take a greater stance has to do with the intricate and difficult nature of policy-making itself, with the PWD tied to a City Council that has its own concept of what is best for its constituency.

Another prohibiting factor is the lack of pilot projects to highlight the potential advantages of conventional sanitation and to prove its safety. The fact that no pilot projects exist is tied to the fact that many individuals in the policy community remain wedded to the notion that the primary drawbacks of the current centralized system are the CSOs, which can be solved by increasing stormwater retention areas, and the fluctuating cost of energy, which can be addressed by investing in energy-producing technologies. At UPenn and Drexel, the comparative amount of research focused on water and wastewater, and specifically on sustainable solutions to water and wastewater problems, is dwarfed by similarly ranked international universities. The leadership role that academia plays in areas where sustainable sanitation pilot projects are implemented is lacking in Philadelphia. Furthermore, the survey hinted at the possibility that some influential academics are just as committed to centralized wastewater management, with a few improvements, as employees of the PWD.

The survey also revealed what could be construed as the burgeoning foundations of a paradigm shift. Almost half of the respondents made reference to concepts of sustainable sanitation and declared the current system unsustainable. Referring back to the authors who originally outlined the structure of wastewater paradigms, Novotny et al (2010), predict that the situation in Philadelphia is to be expected. The transition to the fifth paradigm, they state, will be in most cases a gradual one due to the immensity of the infrastructure and the need for alternative solutions to be optimized. The first step from the fourth paradigm towards the fifth will be marginal pricing, they state, "because the replacement of the old infrastructure will start with the existing most costly component; for example, new nutrient, heat, and energy recovery facilities will replace old and very expensive to operate and maintain secondary (activated sludge) and tertiary treatments with high energy demand and chemical cost" (Novotny et al., (p. 97). The PWD has taken steps in this direction, although it remains to be seen how much of the funding raised will go towards decentralized wastewater technology in addition to the decentralized stormwater technology that is already under construction.

Recommendations to facilitate the expansion of the understanding and interest in sustainable sanitation options focus on the two institutions that were the prominent focus of this research. The PWD could ensure that regulations and building codes were written to ensure that no regulatory barriers existed to the implementation of innovative wastewater technologies. Furthermore, the PWD could seek out partnerships with green architecture and design studios to investigate the potential for implementing pilot projects. These projects could be subsidized by federal, state, and local financing options akin to those employed by construction firm behind the Solaire. Likewise, UPenn and Drexel would be wise to recognize the importance of water and wastewater technologies and the role that these infrastructures will play in the long-term sustainability of the city. Since departments and curricula cannot be restructured overnight, they, too, could investigate the potential for implementing sustainable sanitation pilot projects, creating inter-collegiate partnerships to bridge the knowledge gaps. Since their experience in this realm is limited, they could take their cues from universities like ETH Zürich and Wageningen. Certainly, their ability and interest in playing a role in the local and global water and sanitation conversation will impact the future direction of water and sanitation in Philadelphia.

Throughout the course of this project, I have taken a subject matter which piqued my interest 12 months ago, but on which I was almost completely ignorant, and developed it into an interest, which I hope will define the rest of my career. The process was challenging in ways both expected and unexpected and as a result I feel that I have benefited in ways both explicit and subtle. I believe that throughout this experience I have become more acutely aware of the depth and complexity of water and sanitation issues, caught up as they are in larger discussions of politics and personhood. However, I have also become more certain in my conviction that these issues are integral to the viability of the modern world as we know it.

References

Academic Articles & Conference Papers

Bornmann, L., Leydesdorff, L., Walch-Solimena, C., & Ettl, C. (2011). Mapping excellence in the geography of science: An approach based on Scopus data. [doi: 10.1016/j.joi.2011.05.005]. *Journal of Informetrics, 5*(4), 537-546.

British Medical Journal. (2007). Medical Milestones. *British Medical Journal, 334*, 1-20.

Burian, S. J., Nix, S. J., Pitt, R. E., & Durrans, S. R. (2000). Urban wastewater management in the United States: past, present, and future. *Journal of Urban Technology, 7*(3), 33-62.

Costanza, R. (1993). Developing ecological research that is relevant for achieving sustainability. *Ecological Applications, 3*(4), 579-581.

Daigger, G. T. (2009). Evolving urban water and residuals management paradigms: Water reclamation and reuse, decentralization, and resource recovery. *Water Environment Research, 81*(8), 809-823.

Dilworth, R., Stokes, R., Weinberger, R., & Spatari, S. (2011). The Place of Planning in Sustainability Metrics for Public Works: Lessons from the Philadelphia Region. *Public Works Management & Policy, 16*(1), 20-39.

Factura, H., Bettendorf, T., Buzie, C., Pieplow, H., Reckin, J., & Otterpohl, R. (2010). Terra Preta sanitation: Re-discovered from an ancient Amazonian civilisation - Integrating sanitation, bio-waste management and agriculture. *Water Science and Technology, 61*(10), 2673-2679.

Guest, J. S., Skerlos, S. J., Barnard, J. L., Beck, M. B., Daigger, G. T., Hilger, H., et al. (2009). A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater . *Environmental science & technology, 43*(16), 6126-6130.

Hochedliner, M., Steinmuller, H., Oldenburg, M., Schroft, J., Schweighofer, P., & Plattner, G. (2008). *Experiences from the EcoSan full scale pilot project solarCity Linz*. Paper presented at the 11th International Conference on Urban Drainage.

Jewitt, S. (2011a). Geographies of shit: Spatial and temporal variations in attitudes towards human waste. *Progress of Human Geography, 35*(5), 608-626.

Jewitt, S. (2011b). Poo gurus? Researching the threats and opportunities presented by human waste. [doi: 10.1016/j.apgeog.2010.08.003]. *Applied Geography, 31*(2), 761-769.

Kauffman, G., Homsey, A., Belden, A., & Sanchez, J. (2011). Water quality trends in the Delaware River Basin (USA) from 1980 to 2005. *Environmental Monitoring and Assessment, 177*(1), 193-225.

Kramek, N., & Loh, L. (2007). *The History of Philadelphia's Water Supply and Sanitation System.* University of Pennsylvania, Philadelphia, PA.

Kuhlman, T., & Farrington, J. (2010). What is Sustainability? *Sustainability, 2*(11), 3436-3448.

Langergraber, G. (2005). Ecological Sanitation--a way to solve global sanitation problems? *Environment International, 31*(3), 433-444.

López-Illescas, C., de Moya-Anegón, F., & Moed, H. F. (2008). Coverage and citation impact of oncological journals in the Web of Science and Scopus. [doi: 10.1016/j.joi.2008.08.001]. *Journal of Informetrics, 2*(4), 304-316.

Lüthi, C., McConville, J., Norström, A., Panesar, A., Ingle, R., Saywell, D., et al. (2009). *Rethinking Sustainable Sanitation for the Urban Environment*.

Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, A. T., Gregory, J., et al. (2007). Global climate projections. *Climate change*, 747-845.

Perry L. McCarty, Jaehoe Bae, & Jeonghwan Kim. (2011). Domestic Wastewater Treatment as a Net Energy Producer - Can This be Achieved? *Environmental Science & Technology, 45*, 7100-7106.

Quitzau, M.-B. (2007). Water-flushing toilets: Systemic development and path-dependent characteristics and their bearing on technological alternatives. [doi: 10.1016/j.techsoc.2007.04.005]. *Technology in Society, 29*(3), 351-360.

Rauschning, G., Berger, W., Ebeling, B., & Schöpe, A. (Eds.). (2009). *Ecological settlement in Allermöhe, Hamburg, Germany*: Sustainable Sanitation Alliance.

Rockefeller, A. (1996). Civilization and Sludge: Notes on the history of the management of human excreta. *Current World Leaders, 39*(6).

Schuetze, T., & Thomas, P. (2010). *Integrated Resource Management Concept for a Zero Emission Hotel in Berlin, Germany*. Paper presented at the Urban Development and Sustainability – a major challenge for wastemanagement in the 21st century.

Winker, M., Faika, D., Gulyas, H., & Otterpohl, R. (2008). A comparison of human pharmaceutical concentrations in raw municipal wastewater and yellowwater. [doi: 10.1016/j.scitotenv.2008.03.027]. *Science of The Total Environment, 399*(1-3), 96-104.

Winker, M., & Saadoun, A. (2011). Urine and brownwater separation at GIZ main office building, Eschborn, Germany. In C. Israel & E. v. Münch (Eds.), *Case study of SuSanA projects*: Sustainable Sanitation Alliance.

Zeeman, G., Kujawa, K., Mes, T. d., Hernandez, L., Graaff, M. d., Abu-Ghunmi, L., et al. (2008). Anaerobic treatment as a core technology for energy,nutrients and water recovery from source-separated domestic waste(water). *Water Science and Technology, 57*(8), 1207-1212.

Archival Documents

City of Philadelphia Board of Health Report (1859). Philadelphia City Archives of Philadelphia.

City of Philadelphia Board of Health Report. (1876). Philadelphia, PA: City Archives of Philadelphia.

Gibson, J. M. (2002a, April 12, 2006). Notes on the City's First Water Supply and Distribution System. *Clean Water for Life* Retrieved February 27, 2012, from http://www.phillyh2o.org/backpages/MSB_Water.htm#A2

Gibson, J. M. (2002b, April 12, 2006). Notes on Yellow Fever. *Clean Water for Life* Retrieved February 26, 2012, from http://www.phillyh2o.org/backpages/MSB_Water.htm#A1

Hill, E. G. (1905). The bacterial disposal of sewage. *Journal of the Franklin Institute, 159*(1), 1-16.

Levine, A. (2006a, April 12, 2006). 1801: The Need for Pure Water. *Clean Water for Life* Retrieved February 26, 2012, from http://www.phillyh2o.org/backpages/MSB_Water.htm#11

Levine, A. (2006b, April 12, 2006). 1901: The Need for Purified Water. *Clean Water for Life* Retrieved February 27, 2012, from http://www.phillyh2o.org/backpages/MSB_Water.htm#11

Levine, A. (2006c). Drainage for the City. *Clean Water for Life* Retrieved February 26, 2012, from http://www.phillyh2o.org/backpages/MSB_DRAINAGE2/MSB_DRAINAGE.htm#A1

Levine, A. (2006d, April 12, 2006). Human Pollution. *Clean Water for Life* Retrieved February 27, 2012, from http://www.phillyh2o.org/backpages/MSB_Water.htm#11

Levine, A. (2006e, March 12, 2006). Modern Day System: 2001. *Clean Water for Life* Retrieved February 28, 2012, from http://www.phillyh2o.org/backpages/MSB_DRAINAGE2/MSB_DRAINAGE.htm

Levine, A. (2006f, March 12, 2006). Treatment of Sewage. *Clean Water for Life* Retrieved February 28, 2012, from http://www.phillyh2o.org/backpages/MSB_DRAINAGE2/MSB_DRAINAGE.htm

Macfarlane, J. J., & Hicks, G. W. B. (1911). *Textile industries of Philadelphia*. Philadelphia: Philadelphia Commerical Museum.

Minutes of the Select Council of the City of Philadelphia, 1796-1799, Book One. (pp. 266-268). Philadelphia: City Archives of Philadelphia.

Books, Book Chapters & Reports

Hawkins, G. (2006). *The Ethics of Waste: How We Relate to Rubbish*. Lanham, USA: Rowman & Littlefield Publishers, Inc. .

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions* (3rd ed.). Chicago: University of Chicago Press.

Marsalek, J., Ashley, R., Chocat, B., Matos, M. R., Rauch, W., Schilling, W., et al. (2007). Urban drainage at cross-roads: Four future scenarios ranging from business-as-usual to sustainability. In V. Novotny & P. Brown (Eds.), *Cities of the Future. Towards integrated sustainable water and landscape management* (pp. 338-356). London: IWA Publishing.

McCarthy, M. P. (1987). *Typhoid and the Politics of Public Health in Nineteenth-Century Philadelphia*. Philadelphia: American Philosophical Society.

Novotny, V. (2007). Effluent dominated water bodies, their reclamation and reuse to achieve sustainability. In V. Novotny & P. Brown (Eds.), *Cities of the Future: Towards integrated sustainable water and land management* (pp. 191-215). London: IWA Publishing.

Novotny, V., Ahern, J., & Brown, P. (2010). *Water Centric Sustainable Communities: planning, retrofitting, and building the next urban environment*. Hoboken, NJ: John Wiley & Sons, Inc.

Philadelphia in Focus: A Profile from Census 2000. (2003). Washington, D.C.: The Brookings Institution Center on Urban and Metropolitan Policy.

Reinhard, S., & Folmer, H. (Eds.). (2009). *Water Policy in the Netherlands: Integrated Management in a Densely Populated Delta*. Washington, DC: Resources for the Future

Speers, A. (2007). Water and cities - overcoming inertia and achieving a sustainable future. In V. Novotny & P. Brown (Eds.), *Cities of the Future. Towards integrated sustainable water and landscape management* (pp. 18-31). London: IWA Publishing.

Swyngedouw, E. (2006). Metabolic urbanization: The making of cyborg cities. In N. Heynen, Kaika, M., & Swyngedouw, E. (Ed.), *In the nature of cities*: *Urban political ecology and the politics of urban metabolism* (pp. 21-40). London: Routledge.

Government Documents

American Society of Civil Engineers. (2009). *Report Card for America's Infrastructure*. Reston, VA.

City of Philadelphia. (2009). About City Council. Retrieved March 14, 2012, from http://www.phila.gov/CityCouncil/about.html

City of Philadelphia. (2012). *Resolution No. 120001*

Standards for Onlot Sewage Treatement Facilities. Recycling toilet, incinerating toilet or composting toilet § 73 (n.d.).

Delaware River Basin Commission. (December 22, 2009). *Storm of 1962* Retrieved 2012, March 11, from http://archives.delaware.gov/collections/aghist/0901.shtml#TopOfPage

Delaware River Basin Commission. (2012). *About DRBC*. Retrieved from http://www.state.nj.us/drbc/about/budget.html.

Development Planning Unit. (2012). Research. Retrieved April 5, 2012, from http://www.bartlett.ucl.ac.uk/dpu/research

Interstate Commission on the Delaware River Basin (INCODEL) (December 22, 2009). *Storm of 1962* Retrieved March 11, 2012, from http://archives.delaware.gov/collections/aghist/0903.shtml

Levine, A. (2010, May). Sewers, Pollution, and Public Health in 19th Century Philadelphia. *Pennsylvania Legacies, 10,* 14-19.

Office of Economic Opportunity. Philadelphia Biosolids Services. Retrieved September 25, 2011, from http://oeo.phila.gov/forms/Biosolids%202011.pdf

Pennsylvania Department of Environmental Protection. (2012). Division Missions. Retrieved March 18, 2012, from http://www.portal.state.pa.us/portal/server.pt/community/about_water_supply/10536/division_missions/553825#Water

Philadelphia Water Department. Biosolids Management Overview. Retrieved September 25, 2011, from http://www.phila.gov/water/biosolid_recycle_cen.html

Philadelphia Water Department. Office of Watersheds *Watershed Information Center* Retrieved March 10, 2012

Philadelphia Water Department. Urban Water Cycle. Retrieved September 23, 2011, from http://www.phila.gov/water/urban_water_cycle.html

Philadelphia Water Department. (2009). *Green City Clean Waters. A Long Term Control Plan Update. Summary Report.*

Philadelphia Water Department. (2011). *Questions and Answers about your new water and sewer charges*. Retrieved from http://www.phila.gov/water/Bill/201107RateIncrease_v.pdf.

Philadelphia Water Department. (2012a). Mandates. *Watershed Issues* Retrieved March 9, 2012, from http://www.phillywatersheds.org/watershed_issues/mandates

Philadelphia Water Department. (2012b). Water Infrastructure Management. *What We're Doing* Retrieved March 14, 2012, from http://www.phillywatersheds.org/watershed_issues/infrastructure_management

U. S. Fish and Wildlife Service. (January 20, 2011). Federal Water Pollution Control Act (Clean Water Act). *Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service* Retrieved March 11, 2012, from http://www.fws.gov/laws/lawsdigest/fwatrpo.html

U.S. Environmental Protection Agency. (1999). *Summary of the Listening Sessions: Observations & Recommendations for Guidance and Technical Assistance to Facilitate Water Quality and Designated Use Reviews for Waters Impacted by Combined Sewer Overflows*.

U.S. Environmental Protection Agency. (2007). National Pollutant Discharge Elimination System. Retrieved March 7, 2012, from http://cfpub.epa.gov/npdes/pareas.cfm

U.S. Environmental Protection Agency. (2008, September 12, 2008). Introduction to the Clean Water Act. Retrieved March 7, 2012, from http://www.epa.gov/owow/watershed/wacademy/acad2000/cwa/right1.htm

U.S. Environmental Protection Agency. (2012). Water. *Regulatory Topics* Retrieved March 7, 2012, from http://www.epa.gov/lawsregs/topics/water.html#wastewater

Newspaper Articles

Bauers, S. (2012a, March 6, 2012). Financial woes shake the DRBC*. Philadelphia Inquirer*. Retrieved from http://www.philly.com/philly/health/20120306_Financial_woes_shake_the_DRBC.html

Bauers, S. (2012b, March 30, 2012). Radioactive iodine in Phila. water tied to thyroid patients*. www.philly.com*. Retrieved from http://articles.philly.com/2012-03-30/news/31261499_1_radioactive-iodine-drinking-water-thyroid-patients

Bauers, S. (2012c, March 9, 2012). Who cares about the DRBC*. Philadelphia Inquirer*. Retrieved from http://www.philly.com/philly/blogs/greenliving/Who-cares-about-the-DRBC.html

Graham, T. (2012a, March 8, 2012). Councilman proposes new water and sewer commission*. The Philadelphia Inquirerer (philly.com)*. Retrieved from http://www.philly.com/philly/news/politics/city/20120308_Councilman_proposes_new_water_and_sewer_commission.html

Graham, T. (2012b, February 5, 2012). Phila. Water Dept. wants 28.5% rate hike. *Philly.com*. Retrieved from http://www.philly.com/philly/news/politics/city/20120205_Phila__Water_Dept__wants_28_5__rate_hike.html?c=r

National honors for city's sustainable development. (2010). *The Philadelphia Tribune* May 21, 2010. Retrieved March 30, 2012, from http://www.myvirtualpaper.com/doc/the-philadelphia-tribune/pt052110/2010052401/14.html#14

Praeger, D. (2007, April 15). Scatologically Correct. *New York Times*. Retrieved from http://www.nytimes.com/2007/04/15/opinion/nyregionopinions/15CIpraeger.html

Waterless urinals a go for Comcast Center. (2006, April 5, 2006). *Philadelphia Business Journal*. Retrieved from http://www.bizjournals.com/philadelphia/stories/2006/04/03/daily32.html?page=all

Online Sources

Burwell, S. M. (2011). Reinventing the Toilet. Retrieved from http://www.gatesfoundation.org/speeches-commentary/Pages/sylvia-mathews-burwell-2011-reinventing-the-toilet.aspx

Introduction: Phosphate as an Essential Mineral. (2010). from University of South Florida; Florida Industrial and Phosphate Research Institute: http://www1.fipr.state.fl.us/PhosphatePrimer

Junkins, L. (2011). The 6 Most Corrupt Cities in America. *NakedLaw* Retrieved March 14, 2012, from http://nakedlaw.avvo.com/2011/03/the-6-most-corrupt-cities-in-america/

Leckrone, J. W. (2011). Philadelphia Corruption and Political Culture. Retrieved March 14, 2012, from http://theamericanpartnership.com/2011/09/27/philadelphia-corruption-and-political-culture/

Liddell, H. G., & Scott, R. (1940). A Greek-English Lexicon. Retrieved February 26, 2012, from http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dpara%2Fdeigma

Philadelphia Global Water Initiative. (2012). About. Retrieved April 5, 2012

The Solaire. *Luxury Rentals Manhattan* Retrieved March 31, 2012, from http://luxuryrentalsmanhattan.com/buildings/the-solaire

Synagro Technologies. (2012). Case Studies: Philadelphia Recycling Center. Retrieved March 14, 2012, from http://www.synagro.com/about/case-studies/philadelphia-recycling-center/

The Mill Creek Farm. Frequently Asked Questions. Retrieved March 16, 2012, from http://www.millcreekurbanfarm.org/content/frequently-asked-questions

Tipping, E. (2007). Nature Calls. *Recreation Management Magazine*.

U.S. Green Building Council. (2008a). Finance & Costs. *20 River Terrace - The Solaire* Retrieved March 31, 2012, from http://leedcasestudies.usgbc.org/finance.cfm?ProjectID=273

U.S. Green Building Council. (2008b). Lessons Learned *20 River Terrace - The Solaire* Retrieved March 31, 2012, from http://leedcasestudies.usgbc.org/lessons.cfm?ProjectID=273

U.S. Green Building Council. (2011). What LEED Is. Retrieved March 26, 2012, from http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988

United Nations. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. Retrieved from http://www.un-documents.net/wced-ocf.htm.

United Nations. (1992). *Programme of Action for Sustainable Development.* Paper presented at the Conference on Environment and Development, Rio de Janeiro, Brazil.

United Nations. (2009). *World Urbanization Prospects. The 2009 Revision Highlights*. Retrieved from http://esa.un.org/unpd/wup/Documents/WUP2009_Highlights_Final.pdf.

United Nations. (2011). *World Population Prospects: The 2010 Revision, Press Release*. Retrieved from http://esa.un.org/unpd/wpp/Other-Information/Press_Release_WPP2010.pdf.

United States Environmental Protection Agency. (2002). Combined Sewer Overflows Elements of a Long Term Control Plan. Retrieved March 18, 2012, from http://cfpub.epa.gov/npdes/cso/ltplan.cfm

West Philadelphia Landscape Project. (1997, July 30). Powelton/Summer-Winter Garden. Retrieved March 16, 2012, from http://web.mit.edu/wplp/plan/powel.htm

Personal Communications

Abrams, Glen, personal communication, November 28, 2011.
Beebee, Steve, personal communication, February 10, 2012.
Blau, Laura,personal communication, December 13, 2011.
Brown, Drew, personal communication, January 20, 2012.
Cowley, Doug, personal communication, March 15, 2012.
Crockett, Chris, personal communication, March 8, 2012.
Dahme, Joanne, personal communication, November 25, 2012.
Gallagher, Eileen, personal communication, November 15, 2011.
Gallagher, Patricia, personal communication, March 20, 2012.
Garofalo, Dan, personal communication, November 2, 2011.
Giegengack, Robert, personal communication, October 26, 2011.
Haas, Charles, personal communication, March 5, 2012.
Montalto, Franco, personal communication, January 9, 2012.
Nims, Josh, personal communication, November 29, 2011.
Revlock, Joe, personal communication, January 13, 2012.
Roark, Richard, personal communication, January 18, 2012.
Rosen, Johanna, personal communication, November 5, 2011.
White, Al, personal communication, February 9, 2012.

NPDES sampling data from Philadelphia wastewater treatment plants, January 2011

Table 14: NPDES sampling data from Southeast Wastewater Treatment Plant, Jan. 1, 2011-Jan. 30, 2011 (*U.S. EPA*)

Permit number: PA0026662	Parameter	DMR Value[4]	Units	Statistical Base Code	Permit limit
	Dissolved Oxygen	6.3	mg/l	Avg. monthly	
	BOD5	6	mg/l	Avg. monthly	30
	pH	7.2	S.Y.	Instantaneous Max	9
	TSS	6	mg/l	Avg. monthly	30
	Ammonia-Nitrogen	6.89	mg/l	Avg. monthly	
	Nitrate as N	0.605	mg/l	Avg. monthly	
	TKN	9.4	mg/l	Avg. monthly	
	TP	0.297	mg/l	Avg. monthly	
	Flow	90	MGD	Avg. monthly	
	BOD5 % removal	94	%	Min. monthly % removal	86
	TSS % removal	95	%	Min. monthly % removal	85
	TKN	0.927	mg/l	Daily max	
	TP	0.044	mg/l	Daily max	

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[4] DMR: Discharge Monitoring Value

Table 15: NPDES sampling data from Northeast Wastewater Treatment Plant, Jan. 1, 2011-Jan. 30, 2011 (*U.S. EPA*)

Permit number: PA0026689	Parameter	DMR Value	Units	Statistical Base Code	Permit limit
	Dissolved Oxygen	5.7	mg/l	Avg. monthly	
	CBOD5	10	mg/l	Avg. monthly	25
	pH	7.2	S.Y.	Instantaneous Max	9
	TSS	10	mg/l	Avg. monthly	30
	Ammonia-Nitrogen	10.48	mg/l	Avg. monthly	
	Nitrate as N	0.306	mg/l	Avg. monthly	
	TKN	14.6	mg/l	Avg. monthly	
	TP	0.755	mg/l	Avg. monthly	
	Flow	151	MGD	Avg. monthly	
	CBOD5 % removal	94	%	Min. monthly % removal	86
	TSS % removal	96	%	Min. monthly % removal	85
	TKN	1.1	mg/l	Daily max	
	TP	0.092	mg/l	Daily max	

Table 16: NPDES sampling data from Southwest Wastewater Treatment Plant, Jan. 1, 2011-Jan. 30, 2011 (U.S. EPA)

Permit number: PA0026671	Parameter	DMR Value	Units	Statistical Base Code	Permit limit
	Dissolved Oxygen	7	mg/l	Avg. monthly	
	CBOD5	3	mg/l	Avg. monthly	25
	pH	7.2	S.Y.	Instantaneous Max	9
	TSS	5	mg/l	Avg. monthly	30
	Ammonia-Nitrogen	24.75	mg/l	Avg. monthly	
	Nitrate as N	0.851	mg/l	Avg. monthly	
	TKN	26.93	mg/l	Avg. monthly	
	TP	0.517	mg/l	Avg. monthly	
	Flow	158	MGD	Avg. monthly	
	CBOD5 % removal	97	%	Min. monthly % removal	89.25
	TSS % removal	97	%	Min. monthly % removal	85
	TKN	5.42	mg/l	Daily max	
	TP	0.296	mg/l	Daily max	

University rankings

Table 17: The Times Higher Education World University Rankings, 2011 (*www.timeshighereducation.co.uk*)

World Rank	Institution	Country
1	California Institute of Technology	USA
2	Harvard University	USA
2	Stanford University	USA
4	University of Oxford	United Kingdom
5	Princeton University	USA
6	University of Cambridge	United Kingdom
7	Massachusetts Institute of Technology	USA
8	Imperial College London	United Kingdom
9	University of Chicago	USA
10	University of California, Berkeley	USA
11	Yale University	USA
12	Columbia University	USA
13	University of California, Los Angeles	USA
14	Johns Hopkins University	USA
15	ETH Zurich (Swiss Federal Institute of Technology)	USA
16	University of Pennsylvania	USA
17	University College London	United Kingdom
18	University of Michigan	USA
18	University of Toronto	Canada
20	Cornell University	USA

Table 18: The U.S. News World's Best Universities: Top 400 (*www.usnews.com*)

World Rank	Institution	Country
1	University of Cambridge	United Kingdom
2	Harvard University	USA
3	Massachusetts Institute of Technology	USA
4	Yale University	USA
5	University of Oxford	United Kingdom
6	Imperial College London	United Kingdom
7	University College London	United Kingdom
8	University of Chicago	USA
9	University of Pennsylvania	USA
10	Columbia University	USA
11	Stanford University	USA
12	California Institute of Technology	USA
13	Princeton University	USA
14	University of Michigan	USA
15	Cornell University	USA
16	Johns Hopkins University	USA
17	McGill University	Canada
18	ETH Zurich (Swiss Federal Institute of Technology)	Switzerland
18	Duke University	USA
20	University of Edinburgh	United Kingdom
***Drexel University not listed**		

Table 19: Academic Ranking of World Universities, 2011 (*www.arwu.org*)

World Ranking	Institution	Country
1	Harvard University	USA
2	University of California, Berkeley	USA
3	Stanford University	USA
4	Massachusetts Institute of Technology	USA
5	University of Cambridge	United Kingdom
6	California Institute of Technology	USA
7	Princeton University	USA
8	Columbia University	USA
9	University of Chicago	USA
10	University of Oxford	United Kingdom
11	Yale University	USA
12	Cornell University	USA
13	University of California, Los Angeles	USA
14	University of California, San Diego	USA
15	University of Pennsylvania	USA
16	University of Washington	USA
17	University of Wisconsin-Madison	USA
18	The Johns Hopkins University	USA
18	University of California, San Francisco	USA
20	The University of Tokyo	Japan
301-400	Aristotle University of Thessaloniki	Greece
301-400	Autonomous University of Barcelona	Spain
301-400	Bar-Ilan University	Israel
301-400	Ben-Gurion University of Negev	Israel
301-400	Brigham Young University	USA
301-400	City University of Hong Kong	China
301-400	Clemson University	USA
301-400	Technical University Darmstadt	Germany
301-400	Dresden University of Technology	Germany
301-400	Drexel University	USA

Survey Questions

1. At what organization do you work?
    a. A multijurisdictional government commission
    b. A for-profit company
    c. A college or university
    d. A state government agency
    e. A federal government agency
    f. A not-for-profit company
    g. A local government agency
    h. Other:
2. If you have a bachelor's degree, what best describes the degree you received? Please also include the year you received your degree.
    a. Engineering
    b. Natural Sciences
    c. Social Sciences
    d. Other:
3. Which of the following fields best describes your current area of expertise?
    a. Drinking Water
    b. Stormwater
    c. Sewage
    d. Combination Stormwater/Sewage/Drinking Water
    e. Other:
4. Which of the following categories best describes your current position?
    a. Education
    b. Management
    c. Policy
    d. Research
    e. Implementation
    f. Other
5. How many people are you responsible for (how many people report to you)?
    a. 0
    b. 1-5
    c. 5-10
    d. 10-20
    e. 20+
6. With regard to the field you identified in question 3, please provide a brief definition of what "sustainability" means in that context.
7. Using the definition of "sustainability" that you provided, would you characterize Philadelphia's water/wastewater system as sustainable?
    a. Yes (Please explain. Max 3 sentences.)
    b. No (Please explain. Max 3 sentences.)
    c. No opinion/not applicable

8. If you answered YES to question 7, please identify at what approximate moment in history the city became sustainable. Give a brief explanation of WHY the city was not sustainable prior to this moment. (If you answered NO to question 7, skip to question 9).
    a. The city became sustainable in (.....) because:
9. If you answered NO to question 7, when do you expect the city could achieve sustainability in its water/wastewater system?
    a. 5 years from now
    b. 10 years from now
    c. 15 years from now
    d. 20 years from now
    e. Other:
10. Please identify max 3 strategies the city should pursue to achieve sustainability and indicate whether they are currently pursuing those strategies:
    a. Strategy one:
    b. Strategy two:
    c. Strategy three:

Institution		All Affiliated Documents (1996-2011)	water	wastewater/ "waste water"	sustainability/ sustainable	stormwater/ "storm water"	sanitation	sewage/ sewerage / sewer	ecological sanitation / ecosan
University of Pennsylvania	1996-2011	59,438	733	12	38	0	7	6	0
	1996-2004	24,148	298	5	12	0	3	1	0
	2005-2011	35,290	435	7	26	0	4	5	0
	All Citations		21,759	197	339	0	71	25	0
ETH Zurich	1996-2011	34,167	1,787	110	144	8	4	83	1
	1996-2004	13,455	462	31	23	3	1	32	0
	2005-2011	20,712	1,325	79	123	5	3	51	1
	All Citations		34,914	2,677	902	98	5	1,744	0
University College London	1996-2011	60,837	1,447	33	132	0	22	29	0
	1996-2004	26,702	591	13	51	0	11	17	0
	2005-2011	34,135	856	20	81	0	11	12	0
	All Citations		29,184	721	1,144	0	193	560	0
Drexel University	1996-2011	9,379	300	17	10	3	1	12	0
	1996-2004	2,802	112	3	0	0	0	5	0
	2005-2011	6,577	188	14	10	3	1	7	0
	All Citations		4,507	98	66	4	4	102	0
Technische Universität Darmstadt	1996-2011	3,853	128	27	10	2	1	16	0
	1996-2004	813	20	5	0	0	0	1	0
	2005-2011	3,040	108	22	10	2	1	15	0
	All Citations		1,123	69	41	12	5	39	0
Technische Universität Dresden	1996-2011	6,935	199	21	7	4	1	16	0
	1996-2004	2,630	56	3	1	0	0	3	0

	2005-2011	4,305	143	18	6	4	1	13	0
	All Citations		1,997	189	15	14	6	176	0

Institution		sustainable / sustainability & water	sustainable / sustainability & wastewater / wastewater	sustainable / sustainability & stormwater / storm water	sustainable / sustainability & sanitation	sustainable / sustainability & sewage / sewerage / sewer	sustainable / sustainability & water	sustainable / sustainability & wastewater/ wastewater
University of Pennsylvania	1996-2011	2	1	0	0	1	2	1
	1996-2004	1	0	0	0	0	1	0
	2005-2011	1	1	0	0	1	1	1
	All Citations	59	6	0	0	6	59	6
ETH Zurich	1996-2011	11	0	0	0	3	11	0
	1996-2004	4	0	0	0	1	4	0
	2005-2011	7	0	0	0	2	7	0
	All Citations	100	0	0	0	8	100	0
University College London	1996-2011	12	0	0	0	0	12	0
	1996-2004	3	0	0	0	0	3	0
	2005-2011	9	0	0	0	0	9	0
	All Citations	121	0	0	0	0	121	0
Drexel University	1996-2011	4	2	1	0	2	4	2
	1996-2004	0	0	0	0	0	0	0
	2005-2011	4	2	1	0	2	4	2
	All Citations	10	1	0	0	1	10	1
Technische Universität Darmstadt	1996-2011	2	1	0	0	1	2	1
	1996-2004	0	0	0	0	0	0	0
	2005-2011	2	1	0	0	1	2	1
	All Citations	1	1	0	0	0	1	1

Technische Universität Dresden	1996-2011	4	0	0	0	0	4	0
	1996-2004	1	0	0	0	0	1	0
	2005-2011	3	0	0	0	0	3	0
	All Citations	14	0	0	0	0	14	0