Building Smarter Infrastructure: Resource Productivity in a Residential Development for Steinhatchee, Florida

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Abstract:
Environmental reforms in America have developed a significant repertoire of conservation practices directly proportional to the boom in suburban development since World War II. The chief obstacle to past comprehensive reforms in land development has been the fragmented approach of individual conservation practices, as their particular science and application were developed independently of one another. The following is a case study in design for *The Conservancy*, a "green development" for a 56-unit rural residential community on the Gulf of Mexico. The goal of design and research is to recombine environmental technologies in planning, infrastructure, landscape architecture, and architecture towards more integrated community development. Design methodologies are implemented to address three conservation criteria common to all green economy business models. First is *advanced resource productivity* to ease the energy economy's reliance on nonrenewable resources. Infrastructural logics, otherwise isolated in conventional development, are bundled into a mosaic with new operational overlaps. Second is the *creation of closed-loop energy systems* that promote the recycling of energy and materials to eliminate waste. Building and site utility systems are modeled after "feedback" in biological systems. Third is the *responsible stewardship of existing resources* that harness the ecology to create sustainable land use configurations. Landscape and architecture are integrated into a unified planning module as biological systems serve urbanizing functions. Since the lack of integrative thinking has been the obstacle to sustainable land development, recombinant design modalities, such as those used in *The Conservancy*, rather than technological innovation, will play the more critical role in developing sustainable environments.

Introduction:

Suburban Infrastructure, Environmental Reform and Green Development

Environmental reforms in America have developed a significant repertoire of conservation practices directly proportional to the boom in suburban development since World War II. Though we have not avoided the subsequent sprawl resulting from ill-planned suburban growth, reform initiatives have provided us with new conservation planning and design strategies to reorient the direction of suburban growth towards greater sustainability. The chief obstacle to past comprehensive reforms in land development has been the piecemeal approach of individual conservation practices as their particular science and application were developed independently of one another.

Individual reforms over the last 50 years have addressed land use, septic tank pollution, water quality, wildlife protection, energy efficient home design, erosion control, and wetland and floodplain protection in their relation to suburban residential development (Rome: 260). Yet, their applications were never administered in a collaborative manner. Among other reasons, obstacles to integrated design standards were mostly due to the fragmented nature of political authority in the United States, the resourcefulness of the building industry in avoiding regulation, and the strength of individual property rights politics in resisting holistic planning (Rome: 266). Thus, the bedrock value environmentalists placed on synergistic management and design—that everything is connected to everything else—was historically impossible to exercise.

Since buildings now consume over 30 per cent of our national energy budget and 60 per cent of our electricity (Rocky Mountain Institute: 7), institutionalized incentives are encouraging "smart growth", with particular consideration for the flows of energy in the development of land and buildings. Recent community developments have successfully overcome financial and political barriers to achieving profitable projects that integrate progressive social and environmental goals. Known as "green development", this emerging paradigm in real estate development emphasizes natural resource productivity and conservation. Here, natural resources are viewed as a form of economic capital in terms of their positive capacity to provide energy and life-affirming ecological services. Their negative outputs in the form of waste, pollution, and non-renewability are liabilities no longer ignored in real estate cost-benefit analyses. Realization of the conservation criterion governing green development requires different standards in design goals and methodologies. The goal is to achieve what author, Ernst von Weizsacker calls the "factor four principle: doubling wealth while halving resource use". Since the lack of integrative thinking has been the obstacle to sustainable land development practices, design as it addresses interdisciplinary modalities, rather than technological innovation, will exert a more critical influence in building sustainable environments. Hence, design methodologies are implemented to address the three conservation criteria common to all green economy business models (Hawken et al: 10). First is *advanced resource productivity* to ease the energy economy's reliance on nonrenewable resources. Second is the *creation of closed-loop energy systems* that promote the recycling of energy and materials to eliminate waste. Third is the *responsible stewardship of existing resources* that harness the ecology to create sustainable land use configurations. Such criteria will direct design towards more integrated methodologies that leverage economic, ecological, and aesthetic processes in land development.

Integrative Design Methodologies

Recombination is the key logic behind design methodologies implemented to realize the three-part conservation criteria of green development. Recombinant design employs integrative methodologies in three ways. First, in order to realize greater resource efficiency, project planning bundles different, infrastructural logics otherwise isolated in conventional development. Services related to transportation, waste treatment, water supply, stormwater remediation, and recreation are developed as an infrastructural mosaic to create new operational overlaps. How might infrastructure become less of a transport mechanism and more of an ecology?

In tandem with the first, the second strategy of recombinant design is to model building and site utility systems after "feedback" in biological systems. Feedback is a natural system's capacity for self-correction and responsiveness to internal and external fluctuations acting upon the system. Such capacities are necessary for the creation of functional closed-loop energy systems and effective resource exchange between and within systems.

Third, design addresses landscape and architecture as one planning unit, rather than as isolated systems. The site's biological systems, valued for their ecological services that are difficult to replicate in human infrastructure, are treated as "natural capital". Recombination of biological and human systems accomplishes responsible stewardship of existing resources, establishing an ecological compatibility between development and environmental protection. These three recombinant design strategies propose new land use configurations for exurban contexts without relying on traditional models of urbanism to address the unique logics organizing the suburb.

The following is a case study in design for *The Conservancy*, a 56-unit rural residential community on the Gulf of Mexico. The design's aim is to enhance the ecological capacity of new development through the integration of natural and social systems. Design combines environmental technologies in planning, infrastructure, landscape architecture, and architecture towards integrated community development. Though none of the project's individual design technologies break new ground, their recombination with one another offers new prospects for sustainable real estate development.

Advanced Resource Productivity and Creating Infrastructural Mosaics

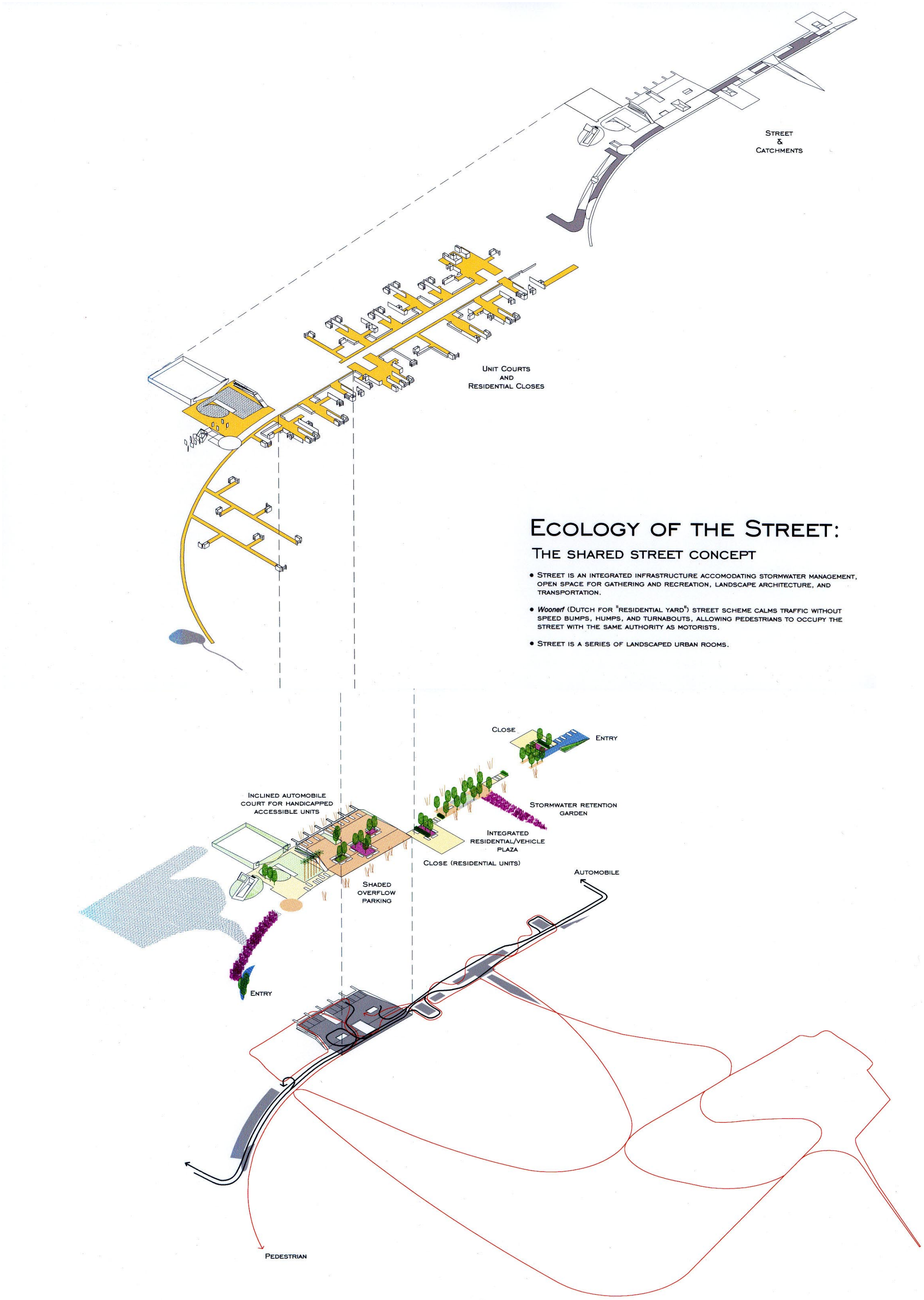
In advanced resource productivity, value and economic vitality are measured by greater efficiencies in the use of natural resources while enhancing productivity. Planning for *The Conservancy* abandons the land-wasting patterns of subdivision design in favor of more integrated land use configurations without sacrificing privacy. The project masterplan features clustered townhouse units around a pedestrian oriented main street to conserve 85 per cent of the site as a wooded preserve and wildlife corridor. Unit clustering, shared auto courts, and commonly held recreational amenities save more than 60 per cent in infrastructure costs from conventional layouts. One of the more novel land uses in *The Conservancy* involves the bundling of different infrastructural logics into a mosaic, with the "shared street" as its unifying element. Just as recombinantion enhances biodiversity in the site ecology, recombinant infrastructure enhances the opportunities for social interaction within the community.

The Shared Street Concept

Local residential streets in America constitute 80 per cent of total national road miles. While they only convey 15 per cent of total vehicle miles traveled (Southworth and Ben-Joseph: 5), many local streets are designed with the same engineering standards instituted for highways. Their spaces privilege the movement of traffic over accommodations for a vital pedestrian life, and this is evidenced by the higher rate of pedestrian fatalities in suburbs than in cities. The civic ecology of the traditional urban street with its mixed uses, pedestrian vitality, and territorial claims from residents via windows or porch stoops—what Jane Jacobs referred to as "eyes on the street"—is absent from the contemporary suburb. The shared street concept is an attempt to integrate housing with pedestrian spaces and vehicular networks. Modeled after the Dutch *woonerf* (meaning residential yard), the main street in *The Conservancy* combines social uses of the street with the needs of local traffic. In the reclamation of the street as a public space populated by pedestrians, cyclists, and children at play, the street is designed as a garden for calming traffic rather than as a transportation corridor for segregating and optimizing traffic flows. The "shared street" as it is known in England, also called the "living street" in Germany or the "integrated street" in Israel has been used in progressive residential communities throughout Japan, Israel, Australia, and Europe, particularly in The Netherlands, Great Britain, and Germany, with a remarkable safety record (Southworth and Ben-Joseph: 118).

Essentially, the street is designed as a series of landscaped urban rooms or yards that integrate walks, plazas, courtyards, and the roadway onto one surface without the use of curbs, sidewalks, and other rigid means for segregating pedestrians and traffic. Playing and walking are allowed everywhere. Engineered traffic calming devices like speed bumps, humps, tables, and roundabouts are avoided in favor of street enclosures shaped to encourage slower speeds and simultaneous pedestrian use. Traffic speed is regulated by landscape groupings that force shallow bends, deviations and undulations in the course of vehicular movement. Bands of decorative paving material, shell rock, and permeable ground covers alternate with asphalt to distinguish the various yards comprising the street. Tree, shrub, and bench arrangements further reinforce the street's configuration as a linear series of yards organizing adjacent residential courts. These residential courts extend the domestic realm of the dwelling unit into the street without sacrificing individual privacy. In contrast to the smooth undifferentiated space of the highway, the shared street is shaped by a porous and fuzzy edge logic characteristic in ecological relationships. The shared street facilitates an active pedestrian life and pioneers a more equitable relationship between automobiles and pedestrians, as it has already proven, particularly in The Netherlands (Southworth and Ben-Joseph: 117).

Stormwater retention gardens for collection and treatment of polluted storm runoff are incorporated into the space of the street. Eliminating the need for unsightly detention ditches and underground sewer lines to transport runoff, decentralized retention gardens with hyper-accumulator plants for absorbing pollutants participate in the creation of the street's urban rooms. The street becomes another component in the site's ecology, providing environmental services like on-site waste treatment, pollution abatement, flood control, enhanced biodiversity, wildlife habitat, and local aquifer recharge. Acting more like a biological filter increasing runoff absorption, the shared street reverses the problems of sediment erosion and runoff channelization associated with impervious road surfaces. Construction and maintenance costs from sewer lines and other catchment infrastructure are eliminated honoring the factor four principle mentioned earlier (doubling wealth while halving resource). Another collateral benefit is the new aesthetic opportunity for spatial expression arising from conceptualization of the street as a landscape. Functioning as a meshwork logic that recombines the biological with the



Ecology of the Street:

The shared street concept

- Street is an integrated infrastructure accomodating stormwater management, open space for gathering and recreation, landscape architecture, and transportation.
- *Woonerf* (Dutch for "residential yard") street scheme calms traffic without speed bumps, humps, and turnabouts, allowing pedestrians to occupy the street with the same authority as motorists.
- Street is a series of landscaped urban rooms.

Figure 1. The Ecology of the Street.

social, planners Michael Southworth and Eran Ben-Joseph note, “streets would not only be evaluated in terms of their capacity to carry traffic, but also environmental quality as measured by noise, pollution, social activity, pedestrianization, and visual aesthetics” (110). Advanced resource productivity works exponentially, enriching social capital as it enhances the biological capital of place.

Figure 2. The Shared Street.

Creation of Closed-loop Energy Systems Through Feedback

Closed-loop systems are cyclical organizations of energy distribution that recycle their own energy flows, approaching self-sufficiency and elimination of the concept of waste. Besides trimming energy budgets based on nonrenewable resources, closed-loop organization decreases environmental stress caused by the human movement of material. Humans now move around more material than nature, geological and atmospheric forces combined (von Weizsacker et al: 237). Excessive material movement creates environmental stress equally as damaging as toxic emission. Feedback in closed-loop organizations would improve economies in material movement through alignment of outputs from one system as nutrients for another. Utility systems designed for *The Conservancy* are modeled after the closed-loop logic governing material flows in nature.

Material Flows: Closed-loop Versus Open-loop Energy Distribution

Nature’s modes of transport are ecologically constructed systems with self-regulating capacities for aligning outputs from one organic system as nutrients for another. As ecosystems mature into multiple feedback loops, their nutrient chains undergo a process of shortening and branching to produce rhizomatous systems of significant biological wealth with progressively less energy needs. Their dendritic path structures favor responsiveness over stability and are readily adaptable to disruptive internal and external fluctuations. Through an internal messaging structure known as feedback (Peet: 75), closed-loop systems are continually self-corrective, recycling and switching energy among alternative paths with a consequent multiplier effect. Matter is regenerative in every phase of its circulation, serving symbiotic functions in composition, decomposition and morphosis. Here, ecological thinking demonstrates that everything is connected to everything else. In contrast, open-loop systems are typified by dissipative linear flows with energy-intensive inputs and non-useful outputs in the forms of pollution and waste (Peet: 13). Industrial production systems are classic open-loop organizations, making man the only species whose outputs are not usable as nourishment for another species (Kibert: 19). Given their closed-loop behavior, ecosystems are paradigms of energy distribution since their "climax" systems are the most efficient users of energy and the concept of waste is nonexistent.

Unlike multiple feedback in biological systems, industrial open-loop dynamics are path dependent, conditioned by narrow measures of productivity, performance, and design. Especially with industrial cultures, open-looped energy systems suffer from an inefficient metabolism, requiring high quality resource investments—usually nonrenewable—with resultant low-grade material outputs of limited functional life spans. This is particularly evident in the diminishing returns intrinsic to productive processes in industrial economies. Based on nonrenewable fossil fuel energy, production often requires 100 to 10 000 times the energy for extraction and processing than available energy returns in the final product (Hawken et al: 50). Expenditures on extraction and processing—a product's or service's embodied energy—represents a cost rarely proportional to functional returns and is further outweighed by post-functional liabilities from pollution, residual toxicity, and long hazardous half-lives. In Germany, this hidden history is known as "ecological rucksack" (von Weizsacker et al: 242), calling attention to the environmental stresses stemming from the movement of material and not just that caused by toxic emission.

Building and Site as Generators of Energy

Infrastructure in green development aims to create energy-neutral environments. Like closed-loop systems approaching maturity, infrastructure will bundle conservation, regeneration, and other ecological services with its primary transport function to achieve a balanced energy economy. Considering the imperative of advanced resource productivity in the emerging green economy, infrastructure will move beyond energy consumption to become a net producer of energy. As a foundation for progressive economic development, infrastructure enhances social capacity by transferring surplus energy to the power grid.

Through a combination of passive and active solar building strategies, townhouse units for *The Conservancy* operate as "mini-utilities". Units are equipped with a solar photovoltaic cell system that concurrently serve as a wind scoop to amplify ventilation, and a sunshade to shield portions of the unit and its roof garden. Given Florida's solar availability, conditions are optimal for photovoltaic technology to meet all energy needs and generate a surplus. Surpluses are banked at the power company for credit in an exchange known as "net metering". Photovoltaic systems are supplemented by solar panels for hot water heating and other various passive solar strategies for regulating heat gain and loss. Rather than treat solar building technologies as accessories applied upon completion, unit designs follow a more integral solution for improved energy performance, conservation, comfort, and aesthetic expression.

Since cooling loads dominate energy budgets in Florida and high humidity excludes natural cooling by moisturizing the air, townhouse units are designed to amplify natural ventilation. Raising units off of the ground maximizes their envelopes' exposure to sea breezes. In addition to the use of wind scoops, townhouse units contain an open-air light court at the center. Light courts function as microecologies, filling the center of the townhouse with indirect light while cooling the unit through convective ventilation. Light courts operate as thermal chimneys that vent rising warm air as cooler air is drawn from beneath the unit. The light court's glass skins contain an array of operable windows and terraces to extend indoors the benefits of amplified ventilation. As a governor of further feedback in the unit, light courts include cisterns for rainwater harvesting, and ground water loop heat sinks for air conditioning output. The latter eliminates the need for noisy and unsightly air compressors, preserving the site's acoustical environment.

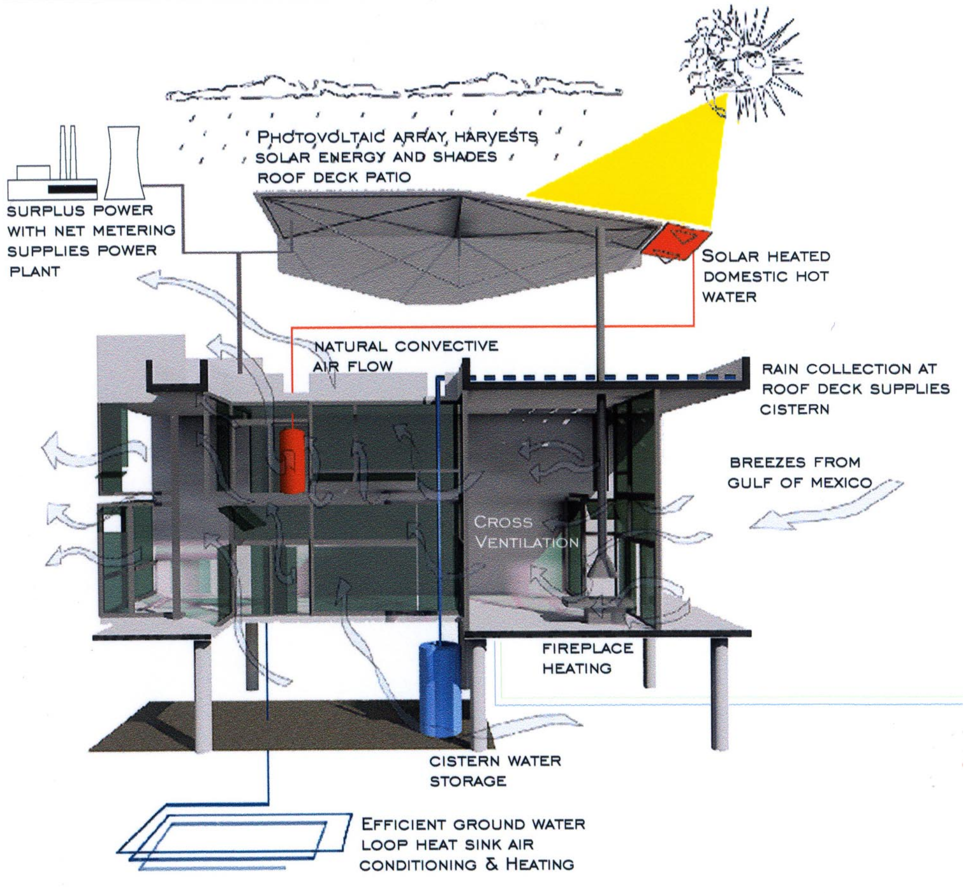


Figure 3. Cross-section Through Interior

Wastewater Treatment

The circulation of water is the single most important life supporting service provided by nature and sets the limits for nature's ability to function. Since wastewater constitutes 80 per cent of all annual waste flows in America (Hawken et al: 51), the impact of its movement on land development is significant. Designed as elaborate transport systems to relocate waste from its source points, water treatment infrastructure projects the same environmental liabilities as other open-loop systems. First, conventional wastewater infrastructure produces toxic byproducts and uses even more toxic substances like aluminum salts (linked to Alzheimer's disease) to mitigate the effects of its initial treatment outputs. Second, treatment processes use hazardous chemicals like chlorine, which, when combined with organic matter, produce carcinogenic residues. Third, centralized wastewater treatment plants are not cost effective, requiring large federal subsidies for their construction (Todd and Todd: xvi). Nor are they energy efficient. *The Conservancy* uses constructed wetlands, akin to "living machines", as a substitute for the conventional mechanical treatment facility. Since sewage contains an abundance of valuable nutrients like nitrates, potash and phosphates (Todd and Todd: xvii), waste treatment systems should be organized as recycling facilities, rather than as disposal systems.

The use of constructed wetlands as core components in decentralized water treatment is gaining acceptance worldwide. Engineer, Scott Wallace likens wetlands to: "the 'kidneys' of our planet, wetlands exchange dirty contaminants for clean, pure water and provide wildlife habitat in the process" (57). In a process known as bioremediation, combinations of living plant and microbe communities are engineered to neutralize volatile compounds in wastewater and recycle their byproducts back into the environment without the use of toxic chemicals. More specific examples of bioremediation, like phytoremediation for instance, incorporate hyper-accumulator plants like those from the Brassica plant family (cabbage, mustard, and radishes) to absorb toxic metals. Cabbage, in particular, is an excellent accumulator, absorbing metal deposits up to 1 000 times higher than concentrations in surrounding soils (Grace: 151). In addition to facilitating nutrient exchange, wetland plants and soils function as biological filters, trapping colloidal particles like petroleum hydrocarbons and otherwise hard to break down suspended solids. Through a treatment train of nutrient exchange and mechanical filtering, constructed wetlands use closed-loop logic in eliminating the production of waste while lowering construction and maintenance treatment costs by as much as 60 – 95% (Rocky Mountain Institute: 146).

To naturally treat wastewater at *The Conservancy*, an on-site treatment plant combines ultraviolet disinfection—replacing chlorination, which produces excess ammonia—with constructed wetlands as core treatment strategies. Wetland design varies from one region to another based on climate and site ecology. However, the basic wetland cell for wastewater treatment is a waterproof, rock-lined pond housing local hydrophytes, or flood tolerant plant species like cattails, bulrushes, reeds and other hard tissue plants. Unlike stormwater treatment, a more narrow range of plants is chosen for its vigorous rooting structures, which attract productive microbial bacteria to promote oxygenization in an otherwise anaerobic root zone. The cell cross-section accommodates a combination of anaerobic and aerobic conditions driving many healthy chemical transformations produced by the interface between plants and sediment (Wallace: 58). Treated effluent is discharged at twice the purity index than water treated in a conventional system, requiring negligible energy input for pumping and aeration. Treatment cells in this particular closed-loop system become internal links in larger biological treatment trains, serving as switching mechanisms to redirect cleaned effluent towards other purposeful uses. Effluent is harvested as irrigation for organic community gardens, aquifer and groundwater recharge, and as a gray water supply for domestic uses not requiring the highest quality water. The latter should cut potable water consumption by as much as 40 per cent since flushing toilets and washing driveways do not require drinking grade water.

Side effects of biological treatment, like that from increased mosquito population, are mitigated through the intensification of feedback protocols. Integrated pest management introduces local bat species and mosquito fish into the treatment ecology. Mosquito fish feed off of mosquito larvae while bats typically consume hundreds of mosquitoes in an evening. Feedback protocols also eliminate odors typically associated with waste treatment since odors are nonexistent in treatment systems that balance inputs with outputs. Organic treatment systems eliminate the usual source of odor that stems from hydrogen sulfide produced in systems lacking aerobic capacity (Campbell: 187). Closed-loop dynamics resolve their own imbalances since they create ever more productive feedback as they approach climax maturity. Wastewater treatment infrastructure then, may prove to be the most radical example of recombinant infrastructure as its protocols abandon steel, concrete, and chemicals to embrace the function and aesthetics of biological meshworks.

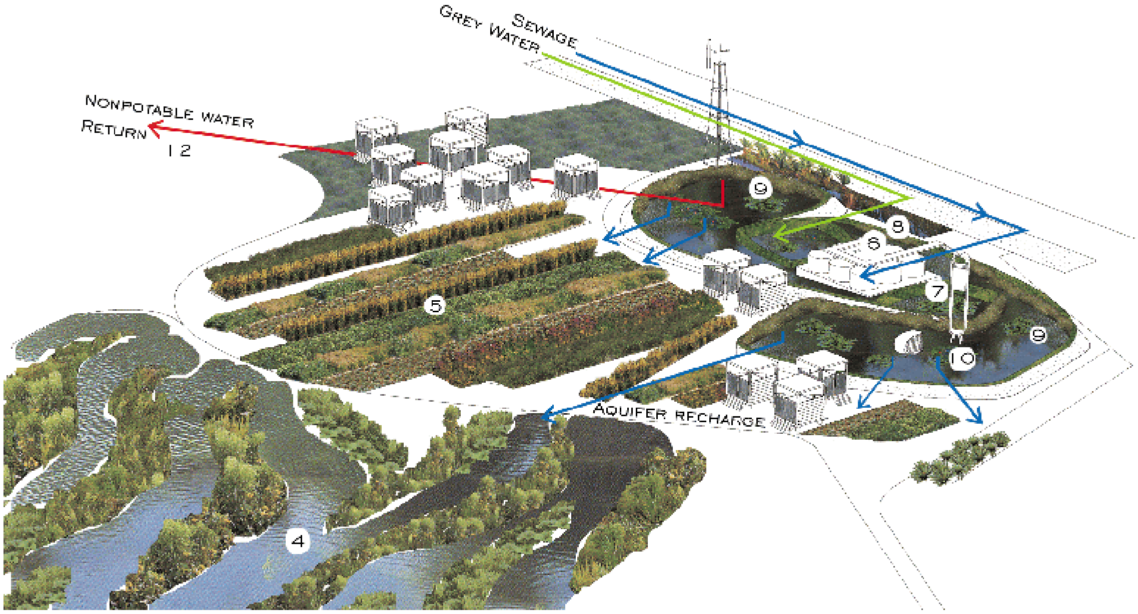


Figure 3. Wastewater Treatment Garden.

Responsible Stewardship of Existing Resources and New Land Use Configurations

Responsible stewardship of natural resources involves more than the preservation of environmentally sensitive areas set apart form the city. Environmental reform can no longer exclude the city from the theoretical and practical considerations of the ecological sciences. Meaningful stewardship now involves the integration of environmental and urban systems. It is now understood that biological systems can serve urbanizing functions (see Platt et al). Indeed, recombinant design seeks an ecological capacity in infrastructure to create intelligent systems with a high degree of interconnectedness and positive feedback. Material exchange in infrastructure for *The Conservancy* will provide collateral services like natural resource regeneration, conservation, and nutrient production, entailing more integrated land use configurations than those produced by classic zoning patterns.

Stormwater Treatment

The stormwater management plan for *The Conservancy* completes the hydrological loop in the delivery of ecosystem services. While the dynamics between storm and waste treatment differ, environmental consequences from stormwater should not be slighted as the first half-inch of urban runoff from a storm event has a pollution content greater than that of raw sewage (Cavanaugh and Spontak: 86). Rather than channelize stormwater runoff into unsightly, centralized detention basins apart from public space, the objective is to create an ecological meshwork whose movement, storage, and treatment patterns resemble the sheet flow of natural wetlands. Conventional stormwater treatment facilities are simply detention/conveyance systems, whereas retention systems, favored by more ecologically sound water management practices, address problems of water quality, groundwater recharge, and conservation. Detention strategies are simply path dependent, concentrating water pollutants beyond the carrying capacity of local landscapes to biologically neutralize their toxicity. Hydrological infrastructure for *The Conservancy* harnesses water as a biological and aesthetic amenity to organize the neighborhood fabric and open space network.

The proposed treatment train links existing wetlands with constructed stormwater retention gardens. Existing marshes, hardwood forests, springs, wetlands, aquifer recharge areas, and wildlife corridors are preserved and integrated into the hydrological infrastructure. The plan’s full typological range of new retention including biofiltration ponds, swales, stormwater gardens, water harvesting ponds, and marshes creates a community-scaled watershed for treatment, flood control, and biodiversity enhancement. As mentioned earlier, stormwater gardens are integrated within the space of the street, providing a regional character to the street. Ecological feedback governs the functioning of this new treatment network, eliminating the need for gutters, concrete catchments, pipeline, and other transport apparatus used in conventional runoff management. Automobile parking is clumped in stormwater gardens to minimize distances between surface pollutants and their treatment destinations. While land use configurations become more decentralized as ecological functioning entails greater scales of organization, these configurations simultaneously undergo a greater degree of horizontal and vertical integration. The watershed serves equally alongside the street as a planning module for community development, countering the tendencies of open-loop infrastructure towards concentration, while creating aesthetically superior landscapes.

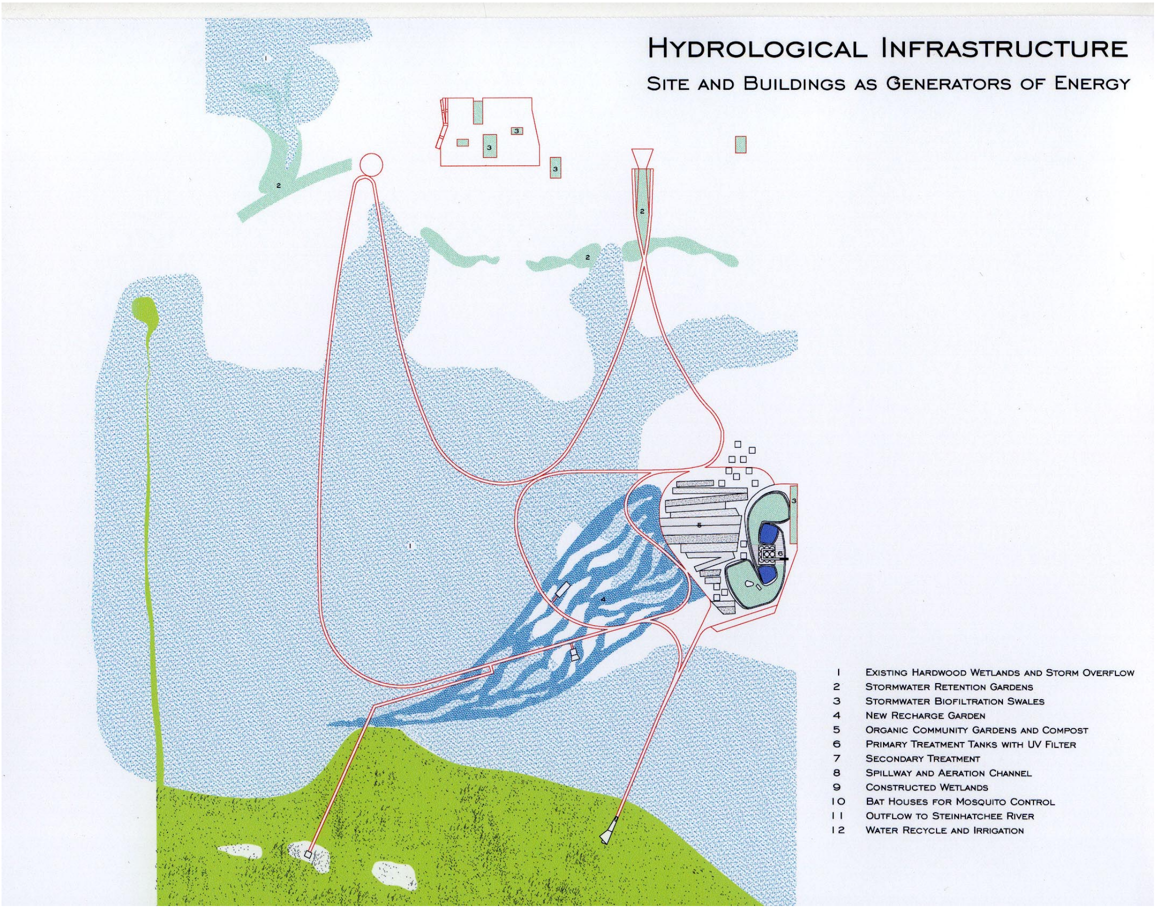


Figure 4. Hydrological Infrastructure.

Conclusion: Infrastructure and Creating New Economies of Feedback

Environmental reforms in America developed land conservation practices that failed to prevent ill-planned exurban growth. The chief obstacle to comprehensive reform has been the fragmented application of individual conservation practices as their particular sciences were developed independently of the others. Recent community developments have overcome political and economic barriers to realize profitable conservation-oriented developments. This new paradigm in real estate development, known as "green development", is based on recombinant methodologies of design. Recombinant design seeks an ecological capacity in infrastructure to create systems with a high degree of interconnectedness and positive feedback. Ecological capacity indicates degree of decentralization, multiple and positive feedback, resource productivity, integration, diversity, and resilience. The collateral benefits will not just add, but multiply.

Spatial configurations from recombinant thinking entail new protocols for formatting space. Standards of design based on the fixed optimization of narrow goals—demonstrated in conventional street design, energy networks, and water management infrastructure—are exchanged for protocols based on the new conservation criteria for radical resource productivity. Protocols supporting greater economies of feedback will bundle otherwise specialized infrastructural logics into a mosaic with novel integrated operational overlaps. Rather than view human habitats begrudgingly as necessary interventions apart from the environment, buildings and their supporting infrastructure should be designed as part of the ecological web. A new planning poetics emerges reflecting novel collaborations between machine and garden as human agency can indeed regenerate life and biodiversity.

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