Research

Summer 2011

LIVING DOCUMENT

Lower Besòs River Restoration
Cheonggyecheon River Restoration
Buffalo Bayou Promenade
Parc Garraf, La Vall D'En Joan
California Academy of Sciences
Potentials for Freeways of Los Angeles

Research compiled by Lily Kerrigan
with guidance from:
Gerdo Aquino
Ying-Yu Hung
Liz Lagedrost
Natalie Sandoval

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LANDSCAPE INFRASTRUCTURE INITIATIVE AT SWA (IRIS):

The Infrastructure Research Initiative at SWA (IRIS) was created as a testing ground for engaging and redefining infrastructure in context with the future growth of our cities and landscapes. Infrastructure, as we know it, no longer belongs in the exclusive realm of engineers and planners. In the context of our rapidly changing cities and towns, infrastructure is experiencing a paradigm shift where multiple-use programming, along with the integration of latent ecologies, is of primary consideration.

Defining our contemporary infrastructure requires a multi-disciplinary team of landscape architects, engineers, architects, and planners to fully realize the benefits to our cultural and natural systems. As an integral part of our daily regimen, infrastructure must be re-imagined for the advancement of our culture, ourselves, nature, and the lifestyles we hope to sustain now and in the future.

INTRODUCTION

Landscape Infrastructure is a methodology that expands performance parameters of a designed landscape to a multi-functional, high performance system. These performances can include systems ascribed to traditional infrastructure. Ideally, landscape infrastructure is flexible and adaptable; it creates community assets that can accommodate new uses and generate new resources.

The idea of landscape infrastructure seems to have formed simultaneously around the world, as outcomes of developmental decisions are compounded, both environmentally and socially. From competitions like WPA 2.0, which focused on redefining the role of infrastructure in the city, to movements like ecological urbanism and green infrastructure, the desire to reconsider the urban condition has manifested simultaneously. A sea-change is beginning in how people view their urban environments.

In this way, the concept of landscape infrastructure seems to be a reaction against typical infrastructure implemented like walls through a city, an increasingly mineralized urban condition, and the heavy-handed solutions of urban waterways. What was once perceived as an asset by developing cities pushing for economic progress and urban comfort is now perceived as an obstacle in the livability and sustainability of a city.

The research presented in this booklet is intended to quantifiably prove the benefits of landscape infrastructure projects through case studies. Performances range from those usually delegated to engineers (flood conveyance) to those that may represent the nascent stages of a new infrastructure (heat island mitigation; PM-10 reduction). The challenges met by projects are also presented, in an attempt to provide an unbiased account of the results of these designs. The last chapter of this booklet focuses on more subjective research for the multi-performance potentials of Los Angeles freeways.

LOWER BESÒS RIVER RESTORATION

BARCELONA, SPAIN

LOWER BESÒS RIVER RESTORATION

BARCELONA, SPAIN

BARCELONA CITY:

Area: 102.2km2

Population: 1,621,537

BARCELONA METROPOLITAN REGION:

Area: 3,241.5km2

Population: 4,992,193

PROJECT/RIVER DATA:

Designer: Barcelona Regional

Cost: $72.92 million total ($20 million for Phase I; $52.92 million for Phase II)

Construction: 1996- present

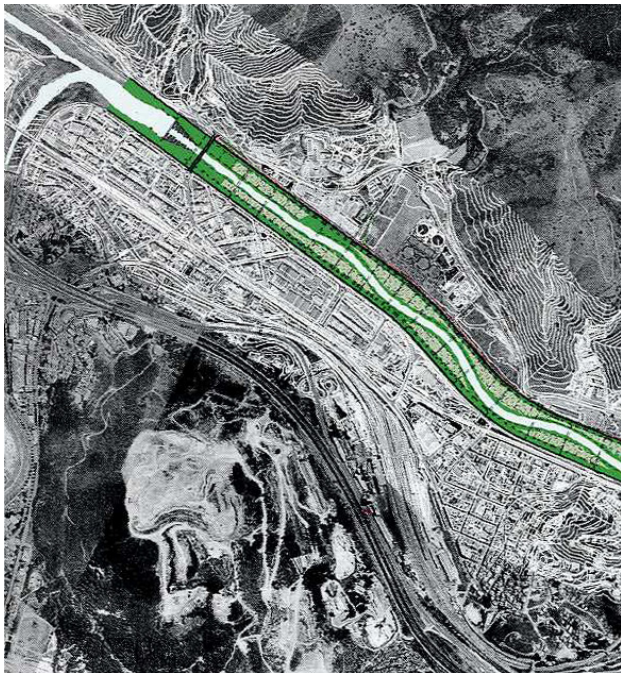
Dimensions: 4m depth, 130m width, lowest 9km

Watershed area: 1000km2

Average Flow Rate: 4m3/s

before

after



The Besòs river is a seasonal river that flows through one of the poorest areas of Barcelona, at the North end of the city. From 1955-1980, the city experienced vast urban growth and a population boom of 3 million. Although the average flow rate of the Besòs is 3.9m^3/s, torrential rainfall patterns can create flash floods within hours. In 1962, the Besòs flooded at a flow rate of over 2,300m^3/s, causing loss of life and damage to urban areas that had grown within its flood plains. This disaster prompted channelization of the river into a flood conveyance system. The original flood plain of

the Besòs of 500 meters in width was channelized to 130 meters.

This channelization prompted new urban growth along the Besòs with the construction of various infrastructures (road, railways, power lines). Water quality of the river degraded with the construction of industrial and other urban buildings along the river which pumped fresh water out the Besòs for use and dumped effluent into the river, virtually creating a flow in the summer season that consists of only high nutrient, polluted effluent. Degradation of the river bed had been managed by the construction of bed sills, which have produced an artificially stepped bed profile.

In 1996, the European Community Commission approved funding for the environmental rehabilitation of the river Besòs, providing 80% of the funding. The goals of the project are to improve the quality of effluent discharge from neighboring waste water treatment plants, improve the flood capacity of the river, and creating public space.

Performances

ACCESS AND SAFETY

ACCESSIBILITY AND SURVEILLENCE

- Data is gathered from sensors placed along the river, as well as satellite, weather radar information and video footage, is input in a macro-computing model. This predictive system, known as the Storm Surge Warning System (SAHBE), is a predictive system that restricts user access during seasonal flood events *(Liat Margolis).*

- SAHBE controls 19 access points into the park. All stairs and ramps have manually controlled gates and LED message signs. *(Liat Margolis)*

- Four staff members throughout the park enforce safety. *(Liat Margolis)*

- Extensive signage is placed throughout the park to notify users of appropriate behavior and risks. *(Liat Margolis)*

1.


2.


3.

Images 1.-3. Images of the Storm Surge Warning System (SAHBE) which serves as a predictive system for controlling user access.

Performances

WATER QUALITY

IMPROVEMENTS IN WATER QUALITY

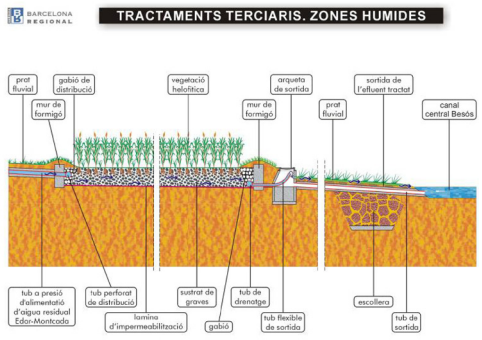
- Source water is diverted, making effluent from riverside wastewater treatment plants the sole flow in summer. *(Source: A.A. Montlleo)*

- Wetlands were constructed to treat water released from wastewater treatment plants. Wastewater is diverted through a drainage system directly into wetlands at a rate of 0.3-0.4m³/s. Here, micro-organisms perform tertiary treatment and break down pollutants through a natural biochemical process in the plant root system. Water is then released below the surface to avoid odors and mosquitoes. *(Barcelona Regional, Liat Margolis)*

- Constructed wetlands on upper 3.1km; treatment cells of gravel 8-25mm in depth, with Phragmites australis and Typha latifolia.
(Honey-Roses)

- The growth of the wetland reeds corresponds with their time-of-need: reeds sprout in Spring and reach their maximum height in the Summer, when water quality is at its lowest. The reeds are then harvested in the winter, with nutrients retained in their roots. *(Les Zones humides website)*

- According to Barcelona Regional, this has resulted in a 85% reduction in Biological Oxygen Demand (BOD), 40% reduction in phosphates, 85% reduction in nitrates, 20% reduction in ammonia.



4.


5.


6.

4. Water is diverted directly from wastewater treatment plants into general treatment cells.

5.-6. Phytoremediation treats water in-situ, through the use of *Phragmites australis* and *Typha latifolia*

Performances

WILDLIFE

IMPROVEMENTS IN WILDLIFE POPULATIONS.

- Ecological indicators, such as the FBILL and IBMWP index, show recent improvements in the quality of the river in the most urban monitoring station (Station B01). However, this could be attributed to high flow rates from recent "wet years," which improve habitats for macroinvertebrates (the BMWP relies on macro-invertebrates as an indicator). In addition, the lack of more urban monitoring stations limits the accuracy of this data. *(Disputacio Barcelona)*

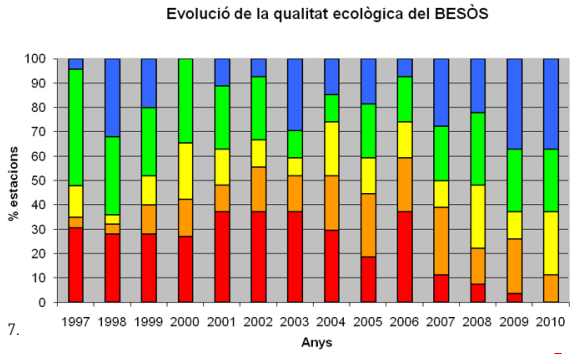
- As of 2011, fish species have increased from zero to three; Eel (Anguilla anguilla), Flathead grey mullet (Mugil cephalus) and Chub (Squalis cephalus). *(Disputacio Barcelona)*

- As of 2011, Bird species have increased from 110 to 200. *(Disputacio Barcelona)*

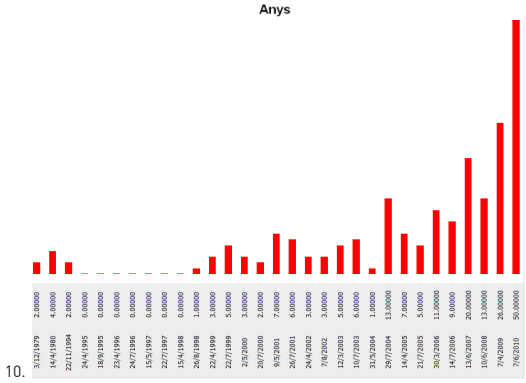
8.

9.

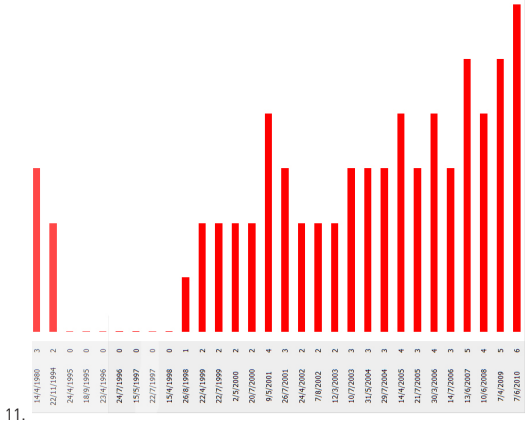
7.



10.



11.



7. According to the IBMWP index, ecological quality has improved substantially since 2006. 8-9. Fish species in the river now include the Eel (8), Chub (9) and the Flathead grey mullet.

11-12. FBill (12) and IBMWP (11) data from station B01 show ecological improvements, especially in the last two years.

Performances

HIGH VOLTAGE LINES

UPGRADE OF ENERGY INFRASTRUCTURE.

- For "aesthetic reasons," 69 electric towers for high-tension cables were removed from the site as part of the restoration project. *(A.A. Montlleo)*

- 51km of electricity infrastructure was rerouted underground. *(A.A. Montlleo)*

- 3 electric circuits of 220kV, or approximately 1,300 Megavolt Ampere (MVA) serves 2 million people. *(A.A. Montlleo)*

*This was the most expensive component of the project. *(Honey-Roses)*

13.

14.

13. Thirty-two miles of electric cables were placed underground.

14. Sixty-nine towere were dismantled along the river.

URBAN CONNECTIONS AND PUBLIC PERCEPTION

- Estimated 300,000 visitors per year. *(A.A. Montlleo)*

- 29 hectares of green space created, with 26 hectares of new park space *(A.A. Montlleo)*

- 19 access points. *(A.A. Montlleo)*

- 5.5km of footpaths and bicycle lanes. *(A.A. Montlleo)*

- Ten years after the restoration, uses have exceeded designed programming. This includes all-day use by families of new park space, fishing near the river mouth, and athletic training along pathways.*(A.A. Montlleo)*

15.

16.

17.

15. Some uses of new park space are unexpected, such as whole day use by families.

16. Footpaths and bicycle lanes totaling 3.4 miles connect the surrounding neighborhoods.

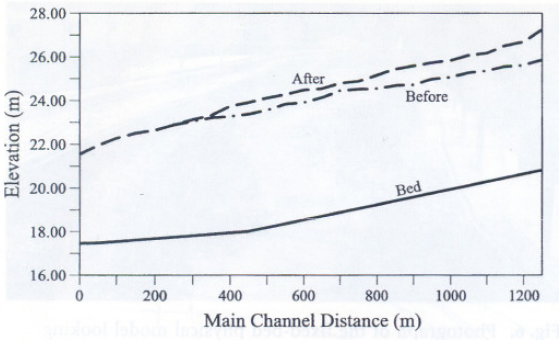
17. The river corridor can be accessed through nineteen access points.

Challenges

FLOOD PROFILE

- According to physical modeling before construction, resistance from the constructed wetlands raised the flow profile of 1,400m of the river.

- This necessitated the construction of higher floodway walls. *(Martin-Vide)*



18.

RIPARIAN GROWTH

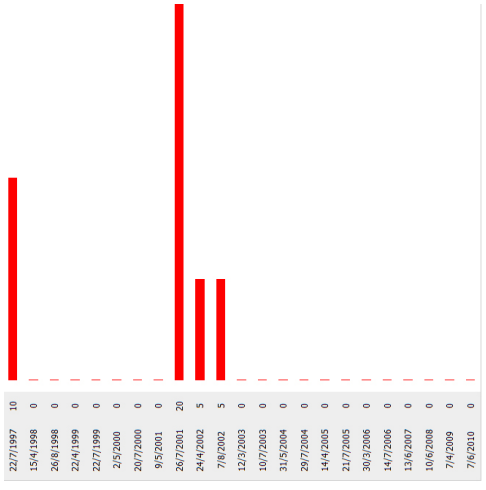
DIFFICULTY ESTABLSIHING THE RIPARIAN PLANT COMMUNITY

- Riparian Quality is rated at 0 out of 100 in 2010 *(Station B01, see page 10)*.

- The artificial reduction of the river width (500m to 130m), lack of natural species along the corridor, and invasive plant communities has challenged the establishment of a riparian plant community. *(Diputacio Barcelona)*.

- Potentially, extremely high flood velocities could be hindering riparian growth. The LA River Masterplan calls for a reduced flow rate to 3.6m/s in order to sustain vegetative growth. With a current flood capacity of 2,532m³/s and an increased watershed area, it is possible that stormwater moves at a rate destructive to riparian establishment.

19.



20.

18. According to modeling by J.P. Martin-Vide, the flood profile of the river raised as a result of the constructed wetlands.

19. Development has hindered riparian growth.

20. Riparian Wuality at the urban monitoring station of the Besòs has remained at 0 since 2003.

Challenges

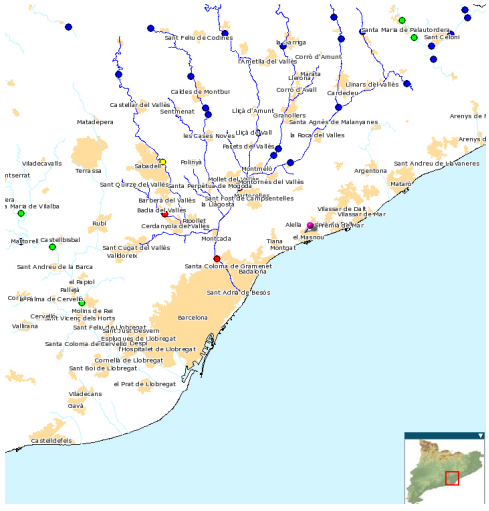
WATER QUALITY

OVERALL POOR QUALITY.

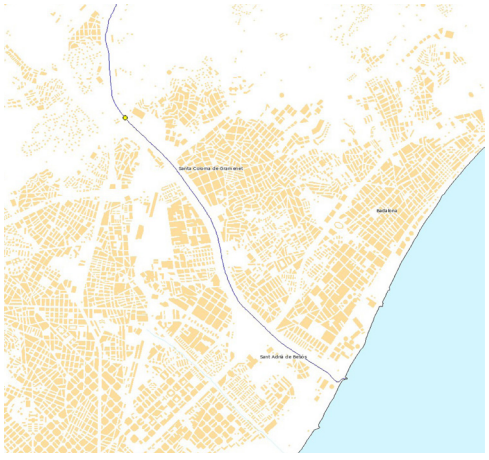
- Despite water quality improvements, data shows that the water in the lower Besòs is not considered healthy for living organisms.

- Data from the most downstream monitoring station (Station B01) shows high phosphate levels (0.65mg $P\text{-}PO_4^{3-}/l$) and nitrate levels (4.4 mg $N\text{-}NO_3^{-}/l$), which will likely produce eutrophication, while ammonia levels (10.13mg $N\text{-}NH_3/l$) were considered "acutely toxic to organisms." *(Diputacio Barcelona).*

- In addition, due to monitoring station placement, available water quality data is not accurate for the lower Besòs. The most downstream monitoring station (Station B01) is still too far upstream from potential urban pollutant sources.



21.



22.

21. The majority of monitoring stations on the Besos River are located upstream, away from major pollutant sources.

22. Station B01, the most downstream monitroing station, is still located far upstream. This makes its accuracy of water quality data questionable.

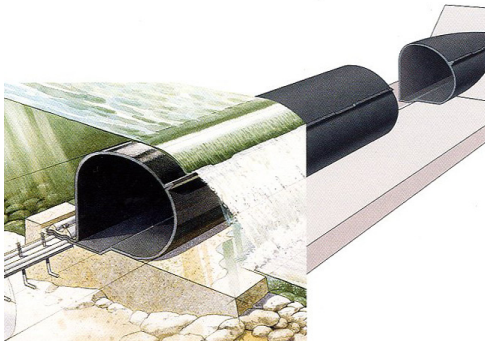
Additional Research

FLOOD CONVEYANCE VS. INFRASTRUCTURAL DEMAND

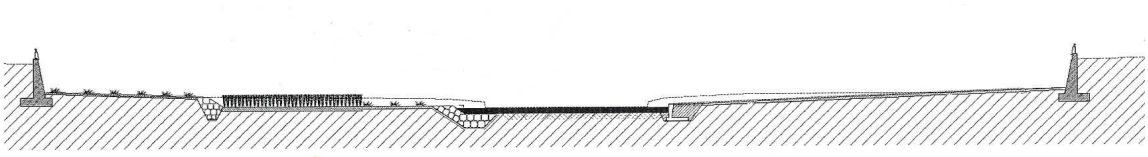
- Eleven pneumatic rubber dams have been installed every 400m to slow down the low flows of the Besòs (average flow of 4m³/s; summertime flow of 2m³/s) into a series of even pools. These dams still guarantee existing flood capacity, deflating to 80% of their volume in 2 minutes, and lying flush with the river bed in 15 minutes. *(Liat Margolis)*

23.

- When the Besòs was originally channelized, flood capacity was at 2,400m³/s, or the equivalent of a 1,000 year flood event. Current flood capacity has been increased to 2,532m³/s. However, in the last 10 years, this flood capacity represents only a 500 year flood event (M. Motlleo). This has been attributed to the decrease of permeable surfaces near the Besòs from changes in land use, increasing the volume of stormwater run-off reaching the channelized river. The remarkable flood capacity of the Besòs may have made the river more susceptible to its increased reliance as a flood conveyance system.



24.



25.

23-24. Pneumatic dams create an even series of pools, and can deflate quickly optimized flood conveyance.

25. The channelization of the river has precipitated reliance on the natural system as stormwater infrastructure.

CHEONGGYECHEON RIVER RESTORATION

SEOUL, SOUTH KOREA

CHEONGGYECHEON RIVER RESTORATION

SEOUL, SOUTH KOREA

SEOUL, SOUTH KOREA:

Area: 605.6 km2 (233.8 mi.2)
Population: 10.3 million

PROJECT/RIVER DATA:

Designer: Seoul Metropolitan Government
Cost: $400 million ($65 million/km USD)
Construction: July 2003-October 2005
Dimensions: 40cm (17") average depth, 20-85m width (65.6-278.9 ft), 5.8 km (3.6 mi.) length of restoration
Supplemental Water: 72 acre feet/day (23,485,700 gallons/day)
Operation/Maintenance Costs (including pumping and treating of water): $6.75 million/year USD.

before

after

HISTORY

1412: 52,800 men build stone embankments and bridges.
1760: 200,000 people are recruited for 57 days to widen and straighten the river and build retaining walls.
1945: After centuries of use as a sewer and laundry facility, the river becomes severely contaminated by the swelling population after the Korean War.
1955-1958: River is encased in concrete
1971: Elevated highway is completed over river corridor.

1991-2001: A series of maintenance projects try to repair crumbling highway

2003: Seoul's mayor breaks ground for restoration of the river; completed 2005

Since the Korean capital was moved to current-day Seoul 600 years ago, the Cheonggyecheon has been an inextricable part of Korean identity and utility. The stream mainly served as an impromptu sewer and laundry facility, until severe contamination and the resulting smell prompted encasement of the river in concrete in 1958. Soon afterwards in 1971, the remaining concrete path was utilized as the base of an elevated highway. But, when a series of maintenance projects failed at repairing the highway from 1991-2001, mayoral candidate Lee Myung-bak won election by promising to unearth the river and bring it back to its previous glory.

What resulted is not a "restoration" of the river to its native form, but a reappropriation and amalgamation of the spaces that preceded it (river, flood conveyance system, urban amenity, highway) with other forms of civic value (fountain). The resulting performances of this restoration, therefore, are as multifarious and complex as the previous lives of the river.

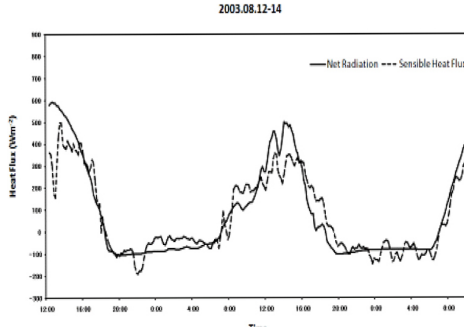
Performances

HEAT ISLAND MITIGATION

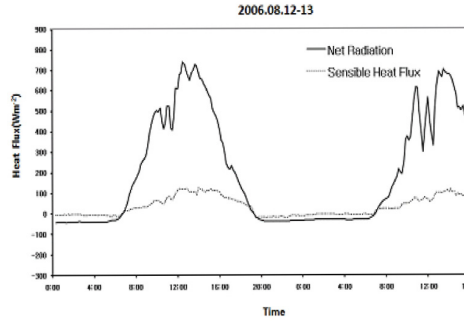
- Exposure of the river produces cool air at the surface of the water (a result of heat storage by the water body), increases vertical ventilation, and recovers wind corridors through this crowded urban area *(Hirofumi Sugawara)*.

- Before restoration, the Cheonggyecheon Highway transferred all energy from solar radiation to the air, the sole effect being an increase in temperature. After restoration, only 20% of the energy from solar radiation was transferred to the surrounding street canyon *(Byung Hyuk Kwon)*.

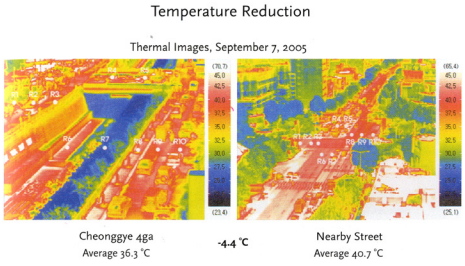
- Temperatures along the river corridor were 3.3 to 5.9°C lower than along parallel roads 4-7 blocks away *(Cevero)*.

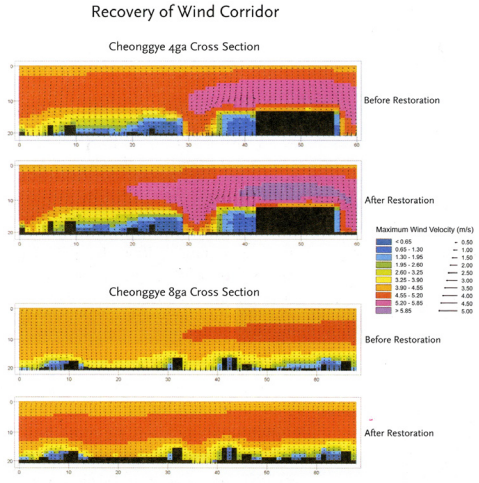


26.



27.





28.

26-27. These graphs show net radiation and sensible before (26) and after (27) the river's restoration.

28. The water body and wind corridor recovery mitigate heat island effects as shown in these images.

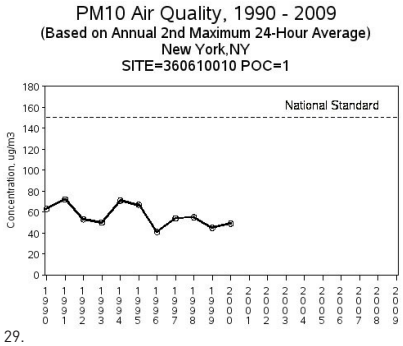
Performances

PM-10 REDUCTION

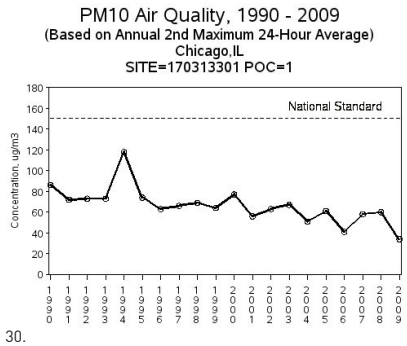
- Prior to restoration, surveys indicated that residents near Cheonggye Street were twice as likely to suffer from respiratory diseases (Kee Yeon Hwang).

- After removal of the Cheonggye Elevated highway and restoration of the river, PM-10 pollution dropped from 74μg/m³ (micrograms per cubic meter) to 48μg/m³ (Revkin).

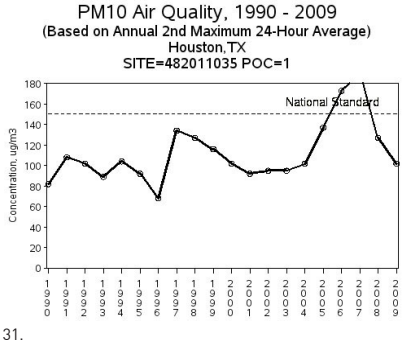
Particulate matter (aka particle pollution or PM) is a mixture of small particles and liquid droplets suspended in the air. PM-10 refers to particles with a diameter of 10 micrometers or less (one-seventh the width of a human hair). These micro-particles are particularly dangerous because of their ability to pass through the throat and nose and enter the lungs, causing breathing and respiratory problems, damage to lung tissue, cancer and premature death. In addition to human health risks, acidic particulate matter can damage man-made materials. In the US, the Environmental Protection Agency has set the national air quality standard for PM-10 at 150μg/m³ in a 24-hour averaging time. The standard is violated if levels exceed that threshold more than once per year, when averaged over a three-year period. (U.S. Environmental Protection Agency). The EPA focuses on "Annual 2nd Maximum 24-Hour Average" as a standard for tracking air pollution in urban areas. So, of the 365 daily averages over a year, the EPA focuses on the second highest of those values when sorted from highest to lowest (Dolwick).



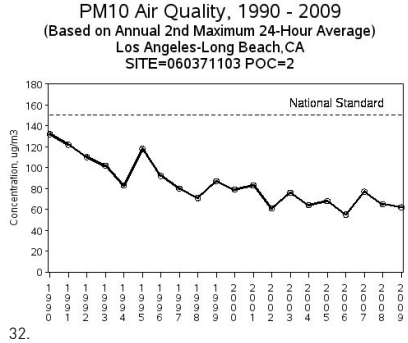
29.



30.



31.



32.

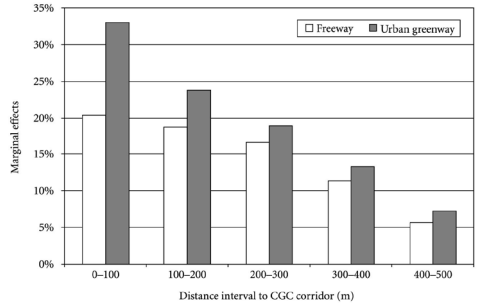
29-32. Monitroing for large U.S. cities (New York, Chicago, Houston and Los Angeles) show PM-10 levels equivalent to higher than PM-10 levels measured near the restored Cheonggeycheon

PROPERTY VALUES

INCREASED VALUE IN PROPERTIES NEAR RESTORATION.

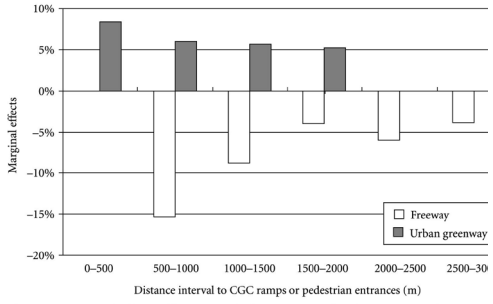
- Commercial properties within 100 meters increased by 13% in property value after the river restoration.
- worth +20% per square meter after restoration (freeway adds commercial value)
-worth +33% per square meter after restoration
** as compared to similar parcels more than 500 meters away*

- Residential properties within 3km. went from having property values from below average to above average:
- worth -4 to-15% per squar meter before river restoration (freeway reduces residential value)
-worth +5 to +8% per square meter after restoration
** as compared to similar parcels more than 3 km. away*



33.

Figure 7. Marginal effects of freeway and urban greenway, by distance intervals



34.

Figure 8. Marginal effects of freeway and urban greenway, by distance intervals

35.

33. Commercial property prices, as compared to parcels more than 500 meters away, before (freeway) and after (urban greenway) restoration.
34. Residential prices went from below average property values to above.

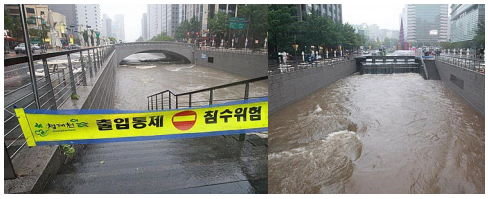
35. Commercial property (in red) is the majority of land use surrounding the Cheonggyecheon River.

Performances

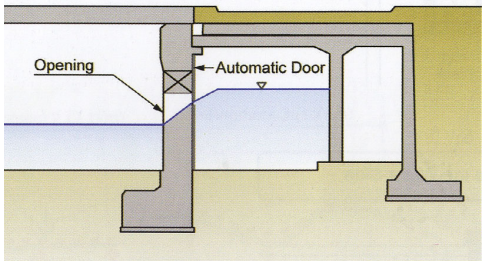
FLOOD CONVEYANCE

- The new river channel has been designed for flood capacity of a 200-year flood event (118mm/hr or 4.6in/hr rainfall) (Park Kil-Dong, Seoul Metropolitan Government, Korea).

- A system of 269 overflow gates have been implemented to expand the volume of stormwater containment upstream during severe flood events (A City and Its Stream, pg 137)



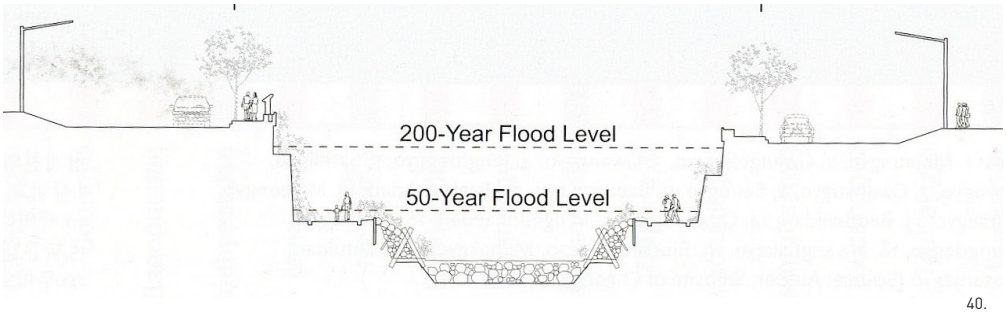
36.



37.

38.

39.



40.

36. The Cheonggyecheon River floods seasonally.

37-39. Overflow gates expand the stormwater volume capacity of the Cheonggyecheon River, an additional safeguard against floods.

40. While still a civic amenity, the recessed section of the river corridor can withstand a 200-year flood event.

Performances

POLITICAL DIVIDENDS

- Lee Myung-bak was elected Seoul's mayor in 2002 on the campaign promise that he would revitalize the Cheonggyecheon river. *(Revkin)*

- The subsequent success of the restoration arguably helped Myung-bak win the presidency of South Korea in 2008 *(Revkin)*.

- River revitalization has since become a political theme for Myung-bak, who recently broke ground on a $19.2 billion public works project to remake the country's four longest rivers: the Han, Nakdong, Kum, and Youngsan rivers. This project has faced opposition from over 400 civic and environmental groups. However, there has been anecdotal evidence of land-value rise as a result of these projects *(Sang-Hung)*.

41.

42.

43.

41. The construction site in Yeoju on the Han River

42. A farmer looks at a billboard illustrating a new weir to be built on the River as part of the "Four Major Rivers Restoration Project".

43. Lee Myung-bak's political success is closely linked to the success of the Cheonggyecheon River restoration.

Performances

ROAD INFRASTRUCTURE

MINIMIZING THE SIZE AND AMOUNT OF ROADS.

- Before restoration, the elevated highway and Cheonggye street provided 12 lanes, carrying 168,556 vehicles per day. After restoration, this high volume roadway was replaced with 4 lanes of reduced speed limit of 50km/hr. This loss of high volume car infrastructure was the most controversial part of the project and faced much resistance *(Park Kil-Dong, Seoul Metropolitan Government, Korea).*

- However, downtown vehicular speed only reduced from 20.8km/h to 20.5km/h. This is because drivers changed their travel behavior in anticipation of the loss of roadway by changing departure times and increasing subway use *(Kee Yeon Hwang).*

- According to commuter surveys, 90% indicated they did not change their commuting times. 5.9% arrived earlier to work while 5.1% arrived later to work as a result of the restoration project *(Kee Yeon Hwang).*

This phenomena is consistent with many theories and studies on traffic behavior, including Triple Convergence Theory by Downs, which states that in a metropolitan city where traffic demand is high and alternative transportation modes are well-prepared, the supply of a new transportation facility can aggravate rather than alleviate traffic jams *(Kee Yeon Hwang).*

Table 6. Change in the number of subway passengers

	23.Jun (Mon.)	24.Jun (Tue.)	25.Jun (Wed.)	26.Jun (Turs.)	27.Jun (Fri.)	Total
Seoul	9,231,514	9,426,058	9,752,527	9,894,974	9,340,174	47,645,247
downtown	1,428,509	1,508,021	1,580,588	1,581,229	1,491,199	7,589,546
	30.Jun (Mon.)	**1.July (Tue.)**	**2.July (Wed.)**	**3.July (Turs.)**	**4.July (Fri.)**	
Seoul	9,637,282	9,557,062	9,825,129	9,533,505	9,881,950	48,434,928
downtown	1,508,577	1,521,601	1,613,891	1,563,475	1,628,271	7,835,815
	7.July (Mon.)	**8.July (Tue.)**	**9.July (Wed.,rain)**	**10.July (Turs.)**	**11.July (Fri)**	
Seoul	9,801,913	9,749,006	9,213,308	9,873,988	9,982,886	48,621,101
downtown	1,594,532	1,597,105	1,494,556	1,624,922	1,650,281	7,961,396

44.

Table 7. Changes of transportation modes

Mode Change	Total (N=1,500)	Business (N=1,000)	Resident (N=500)
No	87.0	91.0	79.0
Yes	6.2	6.8	5.0
No use of any mode	6.1	1.7	14.8
N/A	0.7	0.5	1.0
Total	100	100	100

45.

Table 8. Changes in the use of transportation modes (%)

	Total		Business		Resident	
	before	after	before	after	before	After
walk	16.5	16.6	13.0	12.8	23.6	24.2
auto	19.9	17.4	21.7	18.5	16.2	15.2
subway	32.0	35.6	36.4	40.4	23.2	26.0
bus	19.7	18.1	22.8	21.6	13.6	11.0
other	11.9	12.3	6.1	6.7	23.4	23.6
total	100	100	100	100	100	100

46.

47.

44. The number of subway users in downtown increased by 4.89% by the second week of construction on the project.

45. Pedestrians changed their mode of transportation as a result of project.

46. Commuter surveys show an increase in subway use and walking, and a decrease in bus and auto use.

47. Remnants of the elevated highway remain in the restored stream.

Performances

URBAN CONNECTIONS AND PUBLIC PERCEPTION

- With 22 new bridges (6 pedestrian-only, 16 vehicle and pedestrian) and 20 stepping-stone foot bridges, the restoration project provides urban connections over the natural barrier of the river. *(A City and Its Stream, pg 110,112)*

- However, surveys show that the majority of visits are made on Saturdays and 69% of visits last an hour or more, suggesting the site as a destination rather than a pass-through space *(A City and Its Stream, pg 126)*

- The project has been well-received, with 95% of those surveyed believing the project has contributed either generally or well to environmental components of central Seoul. 80% thought there was an improvement in wind circulation within the city, greater exposure to sunshine, reduction of odor and noise, and better water and air quality as a result of the restoration *(A City and Its Stream, pg 132)*

- An extensive lighting program, including bright street lighting at edges and warmer accent lighting in the stream itself, draws visitors to the site at night, making 26% of all visits during the evening or night *(A City and Its Stream, pg 128).*

48.

49.

50.

48. Different styles of bridges, for both pedestrians and cars.

49. Extensive lighting throughout the project draws 26% of its visitors at night.

50. The river is now an urban destination, with the majority of visits lasting longer than an hour.

Performances

WILDLIFE

IMPROVEMENTS IN WILDLIFE POPULATIONS.
Source water is diverted, making effluent from riverside wastewater treatment plants the sole flow in summer..
(Source: A.A. Montlleo)

Wetlands were constructed to treat water released from wastewater treatment plants. Wastewater is diverted through a drainage system directly into wetlands at a rate of 0.3-0.4m³/s. Here, micro-organisms perform tertiary treatment and break down pollutants through a natural biochemical process in the plant root system. Water is then released below the surface to avoid odors and mosquitoes. *(Barcelona Regional, Liat Margolis)*

Constructed wetlands on upper 3.1km; treatment cells of gravel 8-25mm in depth, with Phragmites australis and Typha latifolia. (Honey-Roses)

The growth of the wetland reeds corresponds with their time-of-need: reeds sprout in Spring and reach their maximum height in the Summer, when water quality is at its lowest. The reeds are then harvested in the winter, with nutrients retained in their roots. *(Les Zones humides website)*

According to Barcelona Regional, this has resulted in a 85% reduction in Biological Oxygen Demand (BOD), 40% reduction in phosphates, 85% reduction in nitrates, 20% reduction in ammonia


52.


53.


54.

52. Fish species diversity was at 4 before restoration and increased to 25 in 2008.

53. Bird species were at 6 types before restoration and increased to 36 in 2008.

54. Insects species went from 15 before restoration and increased to 192 in 2008.

Challenges

WATER FLOW

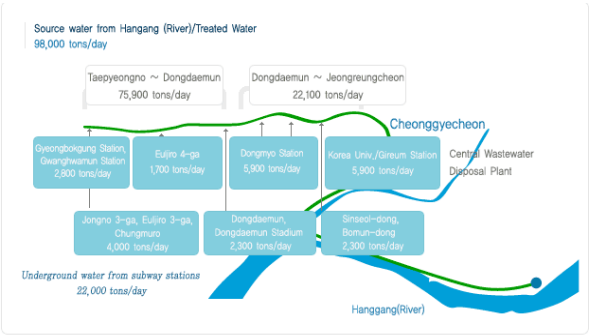
SUPPLEMENTAL WATER SOURCES ARE BEING USED.

- In order to maintain an average depth of 40cm, 120,000m³/day of treated supplemental water is pumped into the Cheonggyecheon *(Revkin)*.

- Supplemental water is supplied from the Han River (via a 7 mile pipe) and ground water from the Seoul subway system *(Revkin)*.

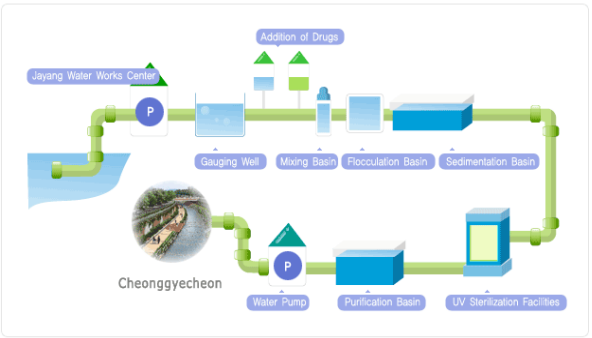
- Due to its proximity to people, water is treated to a Class-2 level, which is designated as suitable for fish native to the Han River (Seoul Metropolitan Facilities Management Corporation). This water is not potable .

Perhaps because water is treated and imported, water loss is minimized to 3% through several methods employed at different stream sections, including a bentonite underlay, liner and sheet-pile system, and sheet pile liners *(A City and Its Stream 108)*.



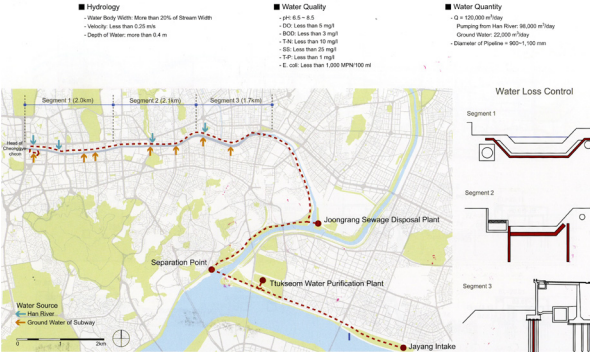
55

The water collected here...



56

becomes the green stream of the Cheonggyecheon running through the city.



57

55. In order to maintain an average depth, supplemental water is supplied from the Han River and ground water sources from various subway stations.

56. Water is treated to a Class-2 level.

z57. It is unclear what envrionmental impacts the redirection of water has on the ecosystem of the Han River.

Challenges

HISTORIC PRESERVATION

- Construction on the Cheonggyecheon River restoration occurred in 27 months. The expected speed of planning and construction (potentially politically-motivated) has been cited as the reason for the disintegration of the historic preservation agenda. Historic preservation was viewed as a obstacle to flood control, traffic, and environmental concerns. This has been a major point of contention between City Hall and citizen's groups *(A City and Its Stream 210)*.

- As a result of public outcry, some historic bridges were reconstructed on site (e.g. the Gwangtonggyo), although not in their original location. Other lost bridges were replaced with poor imitations (e.g. the Supyogyo)*(A City and Its Stream 119)*.

- Many other historic features along the river corridor were lost during construction, including stone emabankments *(A City and Its Stream 210)*.

58.

59.

60.

61.

58 -59. The Supyogy in 1958 was not saved in its original form (58). A poor imitation now sites in its place (59).

60-61. The Gwangtonggyo bridge (60) was reconstructred (61).

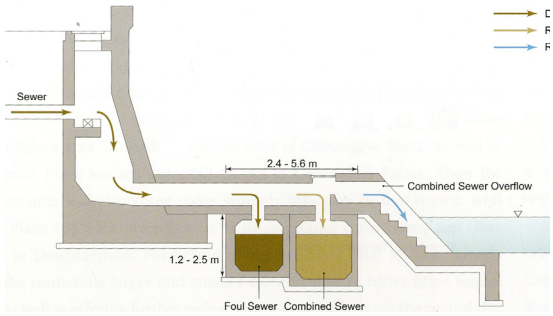
Challenges

SEWER/STORMWATER

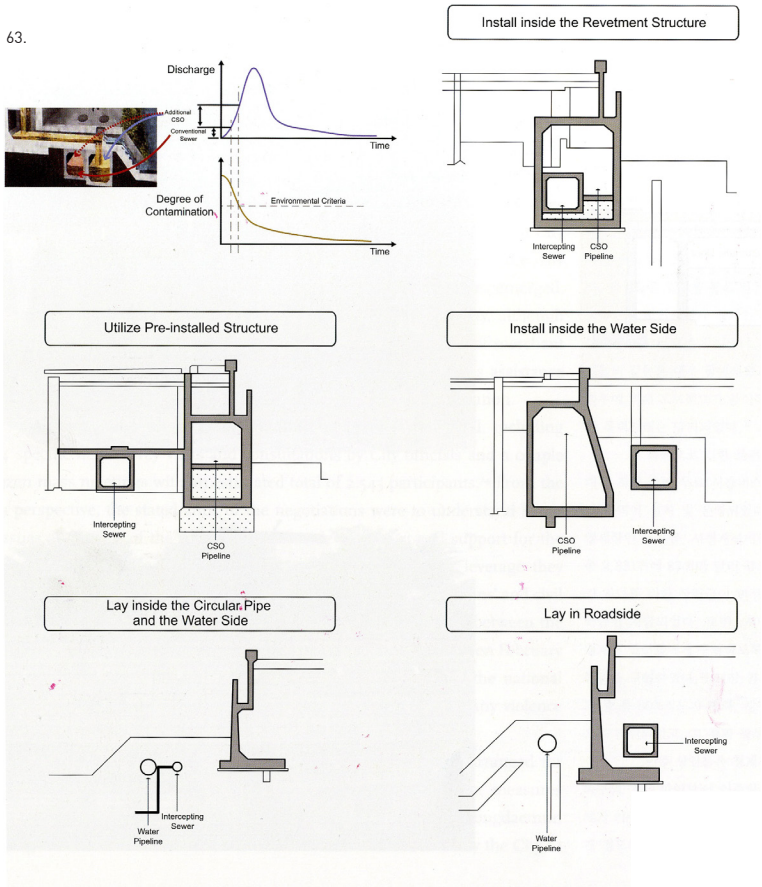
OVERFLOWS INTO RIVER DURING STORMS

- The designers of the project used a double box-channel system to siphon off entering “first flush” stormwater into a sewage conduit. During large storm events, this system overflows untreated stormwater and sewage into the stream *(A City and Its Stream 108)*.

62.



63.



62. A combined Sewer Overflow (CSO) system allows storm and sewage water to flow into the Cheonggyecheon during large storm events.

63. Details of the combined sewage and storm-water system.

Challenges

EUTROPHICATION

Water supplied to the Cheonggyecheon contains a high concentration of phosphorus and nitrogen. These nutrients are from a variety of sources, including supplemental water from the Han River (which does not receive tertiary treatment), soil erosion, runoff containing fertilizers, sewage, and over urban runoff that enters the stream during large storm events (see opposite page). Algae blooms occur at the Cheonggyecheon and require maintenance, including closing down parts of the stream for algae removal. *(A City and Its Stream 135)*

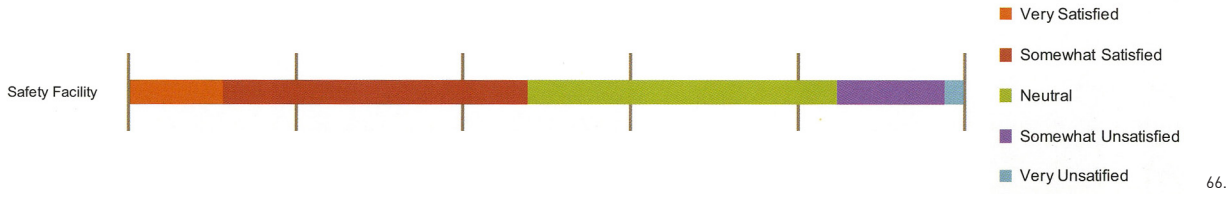
64.

ACCESS AND SAFETY

- Access for disabled users is particularly poor and probably would not meet US ADA standards, with only seven negotiable slopes for the entire 6km stream length, and only two of these provided in popular areas upstream *(A City and Its Stream 132)*.

- Less than 50% of those surveyed felt somewhat or very satisfied with safety, with 15% expressing full dissatisfaction *(A City and Its Stream 135)*.

65.



66.

64. Workers remove algae off rocks in the Chenggyecheon.

65. The section of the Cheonggyecheon is reccessed for optimized flood capacity, however this extreme grade change can make users feel isolated from street level and unsafe.

66. Survey show that most feel unsatisfied or neutral about the safety.

BUFFALO BAYOU PROMENADE

HOUSTON, TEXAS

BUFFALO BAYOU PROMENADE

HOUSTON, TEXAS

HOUSTON CITY:

Area: 579.4 square miles

Population: 2,257,926

PROJECT/RIVER DATA:

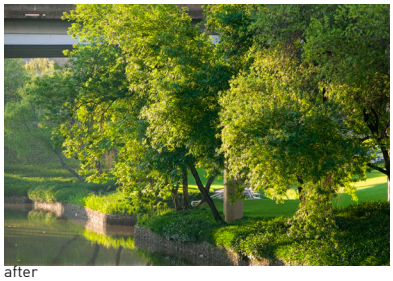
Designer: SWA

Cost: $15 million ($14 million construction;
$1 million landscape fee)

Construction: completed 2006

Dimensions: 1.6 km (1 mile)

before



after

Buffalo Bayou Promenade is a 23-acre recreation area that has transformed an impenetrable urban waste-land into a thriving urban waterfront. It converts a neglected, overgrown, trash-soaked eyesore—intimi-dating to pedestrians and detrimental to flood control efforts—into 3,000 linear feet of urban park. The $15 million project was the result of an historic public/ private partnership to revitalize downtown's urban waterfront. Improvements include naturalization of

gently sloping banks, extensive native landscaping, hike and bike trails, public art, dramatic lighting, 12 new street-to-bayou entryways, a new pedestrian bridge which connects north and south sides of the bayou (for the first time), and interpretive signage.

Performances

EROSION

- Extensive regrading of the site slopes from 2:1 to 3:1 reduces the force of entering water and makes the bank less prone to erosion.

- Designers created a boundary condition with a contiguous gabion system and riparian edge. This creates friction for running water, slowing down as it enters the bayou and safeguarding soil from the sheer stress of water with a vegetative cover.

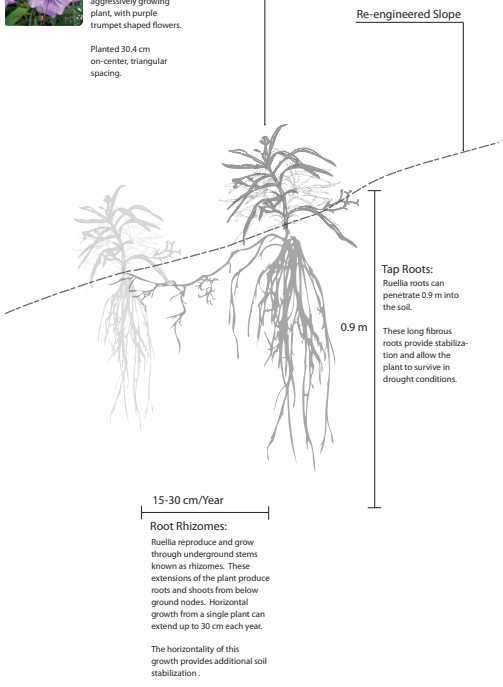
- Flood-resistant riparian vegetation was used (e.g. Ruellia brittoniana, Iris louisiana), which holds soil in place with roots that penetrate up to three feet deep.

- 100% Recycled concrete cobble- lined swales absorb destructive, high volume flows of water pouring from the freeway scuppers, preventing scouring of the bayou banks.

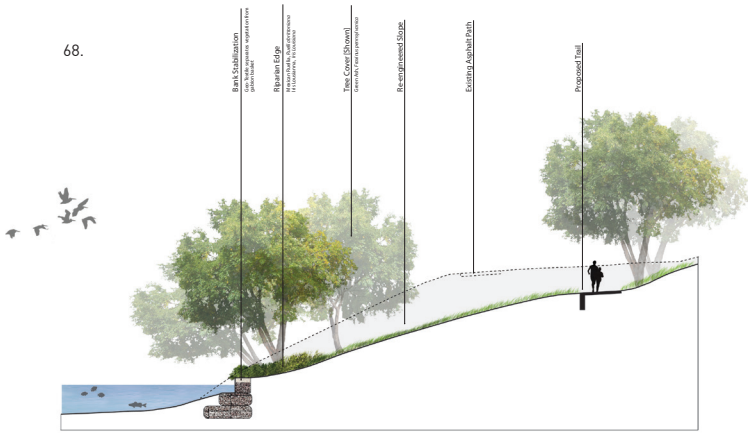
67.

An evergreen perennial shrub, originating in Mexico. Ruellia is a drought tolerant and aggressively growing plant, with purple trumpet shaped flowers.

Planted 30.4 cm on-center, triangular spacing.



68.



67. Ruellia brittoniana (Mexican petunia) has thrived along the bayou banks, stabilizing soil with deep roots.

68. Erosion was controlled through both regrading and the creation of a stabilizing vegetative edge.

Performances

FLOOD CONVEYANCE

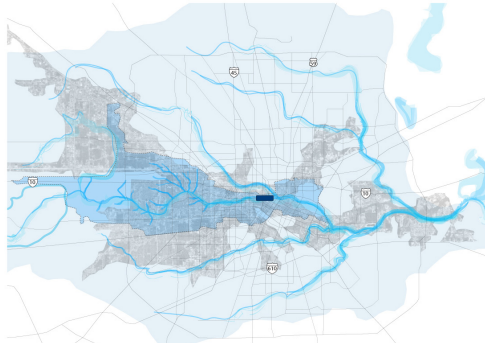
- Retaining flood capacity was an important consideration for the project since the Buffalo Bayou is a major drainage system for the city of Houston.

- Flood storage capacity increasing by 18.65 acre feet through the excavation of 23,013m^3 (812,700ft^3) of soil.

- Base Flood Elevation (BFE) was lowered by an average 2.5 inches across the flood plain through widening of the bayou cross-section, straightening of the channel, and decreasing the roughness coefficient (n-value) of the bayou banks.

- The damaging effects of flooding were reduced through the 400% reduction of stormwater velocity (sheer stress). Prior to channel improvement, the channel was able to withstand less than 2lb/ft^2; after the project, channel can withstand 8lb/ft^2. This was achieved through grading, material choices, and the gabion and planting system.

- Durable design elements (including lighting fixtures, plantings, railings, paved pathways, and public art) can withstand periodic flooding and collisions with floating debris.



69.

70.

71.

69. The Buffalo Bayou watershed covers roughly 267 square kilometers that are almost entirely urbanized, increasing the volume and velocity of water conveyed through the system during a storm event.

70-71. The promenade was designed to withstand flooding.

Performances

URBAN CONNECTIONS

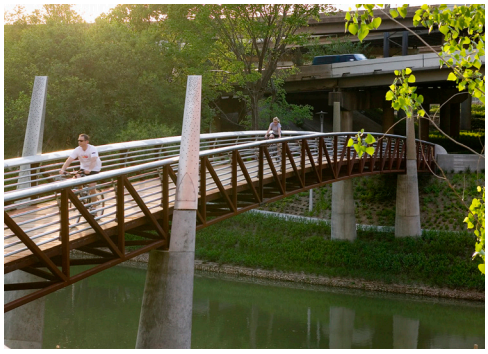
- With a 30ft grade change in some sections of the site, designers concentrated on improving sightlines and increasing access. The slope was laid back and access to the bayou was increased with 12 new street-to-bayou entryways. A North-South pedestrian bridge connects the art district to Houston.

- Contributes 1.2 miles to a 20 mile network of bike and pedestrian paths. This provides a key connection between park space, downtown Houston and the Theater District to the East.Trails are currently being expanded to both the East and North, with 4 miles constructed to the North already.

- All-night lighting is provided for the highly traversed sections of the bayou to allow safe passage for pedestrians between civic/cultural events and residential areas/ parking.

- Provides recreational, interpretive and education opportunities for an estimated 22,500 visitors per year (not including everyday users.

72.



73.

74.

72. Stairways were designed to improve sightlines despite extreme grade changes

73. The first pedestrian-only bridge constructed over the bayou increases non-vehicular connections to the city.

74. Extensive lighting improves the feelings of safety.

Performances

WILDLIFE

IMPROVEMENTS IN WILDLIFE POPULATIONS.

- Approximately 200 healthy, native riparian trees were preserved on-site.

- Weeds and other invasive plants were removed and replaced with 287,000 plants (including native perennials, ground cover and 641 trees) of 71 species.

- A 91.5% water-permeable river edge with gabion sacks and cages allows water egress, mimicking the natural river conditions. Retaining this natural condition of the river promotes a healthy benthic community, an important part of the food chain.

- Native and naturalized riparian plants work with gabion structures to sustain the future hydrological actions of the bayou and provide wildlife refuge.

- Hearsay of wildlife increase as a result of improvements, including regulated water temperature from riparian canopy.

Blue herons on the site are territorial and use the Bayou for nesting and foraging.

Mississippi Mud Turtle,
Kinosternon subrubrum Hippocrepis

Western Chicken Turtle,
Deirochelys reticularia miaria

Red-Eared Turtle,
Pseudemys scripta elegans

Three-Toed Box Turtle,
Errapene Carolina triunguis

Alligator Snapping Turtle,
Macroclemys temminckii

Atlantic Hawkbill Sea Turtle,
Eretmochlys imbricata

Green Sea Turtle,
Chelonia mydas

Leatherback Sea Turtle,
Dermochelys coriacea

House Mouse,
Mus musculus

Great Egret,
Casmerodius albus

American Peregrine Falcon,
Falco peregrinus anatum

Artic Peregrine Falcon,
Falco peregrinus tundrius

Attwater Prairie Chicken,
Tympanuchus cupido attwateri

Bald Eagle,
Haliaeetus leucocephalus

Brown Pelican,
Pelecanus occidentalis

Piping Plover,
Charadrius melodus

Whooping Crane,
Grus americana

Wood Stork,
Mycteria americana

Great Blue Heron,
Ardea herodias

Striped Mullet,
Mugil cephalus

Opossum,
Didelphis marsupialis

Short Tailed Shrew,
Cryptotis parva

Striped Skunk,
Mephistis mephistis

Raccoon,
Procyon lotor

Fox Squirrel,
Sciurus niger

Hispid Cotton Rat,
Sigmoodon hispidus

Eastern Cotton Tail,
Sylvilagus floridanus

Nine-Banded Armadillo,
Dasypus noveminctus

75. There has been anedoctal evidence of increases in populations of species commonly found in the bayou area as a result of environmental improvements.

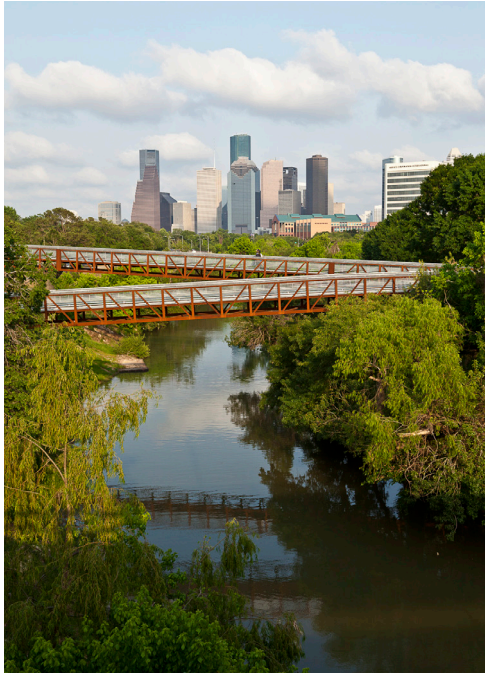
75.

Performances

COST

- Saved $1.2 million through using gabion walls instead of traditional methods for bank stabilization. Gabions were placed in a wet condition, no coffer dams were required. Total cost of gabions and gabion mattress installation was $3,199,229.00. In comparison, bank stabilization using traditional methods of concrete bulkheads and foundations was estimated at $4,400,000.00

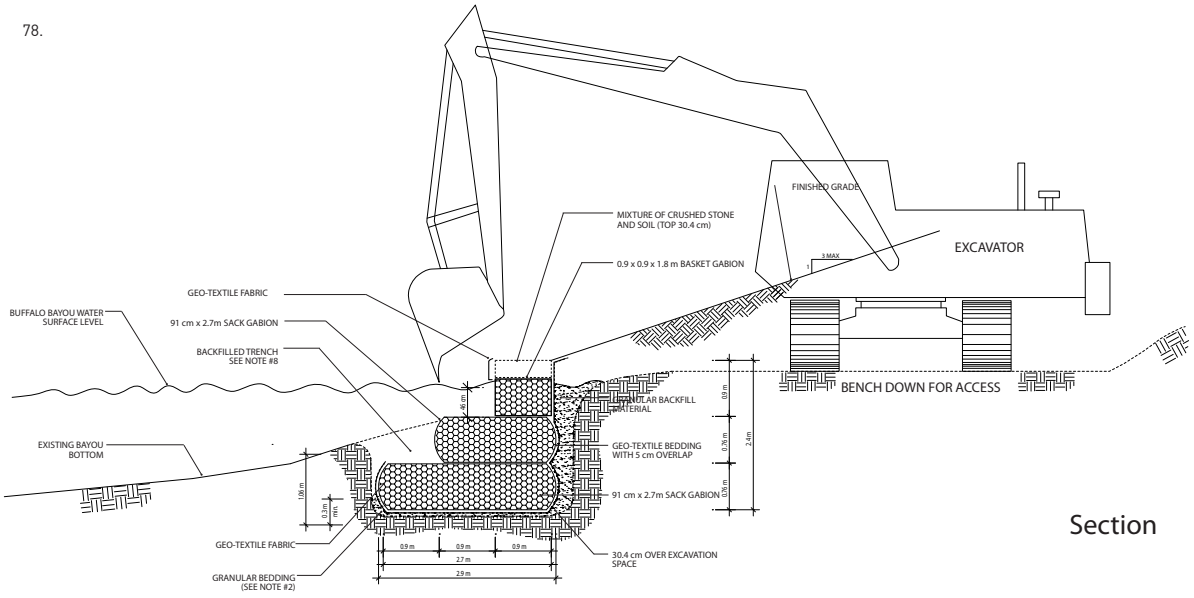
76.



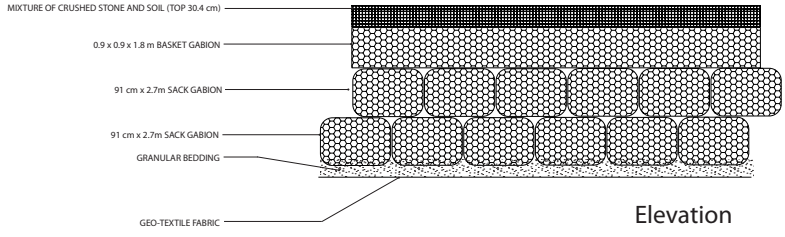
77.

76. An example of traditional bulkheads, which would have been a more expensive and less ecologically sensitve solution to erosion control.

78.



Section



Elevation

77. Gabion cage construction details

Challenes

FREEWAY INFRASTRUCTURE

- Freeway overpasses created obstacles to construction, preventing access to the bayou banks for heavy equipment. Barges were used to access bayou banks for gabion system installation.

- The extreme environmental conditions created under freeway ramps (deep shade, no access to rainwater) necessitated a careful selection of vegetation for these areas, as well as supplemental irrigation. Despite these efforts, some plants still had difficulty establishing.

- The humming noise from cars on the 15 overhead bridges is a constant element of the park experience, making some users uncomfortable. Some users claim casual conversation is difficult in some parks of the promenade.

78.

79.

80.

78. The I-45 interchange soars over the Buffalo Bayou Promenade, creating a complex obstacle for construction equipment.

79. Freeway ramps throw deep shade on slices of land.

80. Irrigated ferns grow under freeway ramps.

Challentes

PUBLIC PERCEPTIONS AND SAFETY

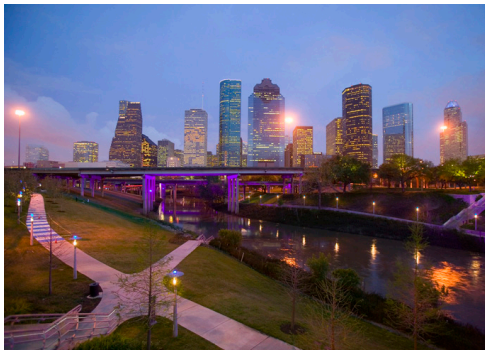
- With some sections of the site at 30ft below grade, and few buildings oriented toward the river, social anxieties and preconceptions about the site's safety continues to be a challenge for this project.

- According to those informally interviewed by a magazine, users feel less safe at night and prefer to ravel in groups or with protection (e.g. mace).

- The Buffalo Bayou Partnership heavily programs the site in an effort to draw large crowds and change the public's preconceptions of the bayou.

- Lighting has been used extensively to increase pedestrian comfort.

81.



82.

83.

81. Planned activies by the Buffalo Bayou Partnership is an important asset to park programming.

82. The promenade is lit all night for safe passage of pedestrians

83. A crowd forms for an event.

PARC GARRAF, LA VALL D'EN JOAN

BARCELONA, SPAIN

PARC GARRAF, LA VALL D'EN JOAN

BARCELONA, SPAIN

BARCELONA CITY:

Area: 102.2km2

Population: 1,621,537

BARCELONA METROPOLITAN REGION:

Area: 3,241.5km2

Population: 4,992,193

PROJECT DATA:

Designer: Barcelona Regional

Cost: $26 million euros

Construction: 2003-2010

Area: 60 hectares

Date opened/closed: 1976-2006

Amount of refuse deposited: 26.6 million metric tons

Landfill dimensions: up to 80 m. deep

before

after

La Vall d'en Joan (Valley of Joan) was the destination for the majority of urban waste from Barcelona and the municipalities of the metropolitan area. The volume accumulating over the thirty two years of its lifespan accumulated to 26,676,000 tonnes.

Barcelona's government wanted to close and seal the landfill and integrate the area with the natural landscape of the surrounding. They also wanted to transform the new dump into a public space (Enttat de Med Ambent de Area Metropotana de Barceona , 2007).

In the later years of the landfill, the operations began disposing of the garbage in a strategic way, making restoration easier. They terraced what is known as zone 4 and created disposal vessels in cells that isolated bodies of garbage from one another by a layer of earth. The mass of the waste is supported by a series of the retaining walls. This way, only the cell that is in the process of being filled is exposed minimizing the negative characteristics of the garbage.

At the Vall d'en Joan site the four important investments that contribute to the affective restoration are waterproofing the vessels holding the garbage, drainage of rainwater, drainage of leachates, and the collection of biogas (Àrea metropolitana de Barcelona, 2003).

Performances

DRAINAGE

SEPARATES RUNOFF AND GROUNDWATER.

- Project aims to separate surface and interior hydrologic regimes in order to isolate and minimize contaminated water

- Since the landfill is in a valley, water naturally drains there

- A series of perimeter trenches were constructed to collect and divert rainwater that falls outside the landfill boundaries

- The water is funneled below the landfill without coming in contact with the waste

- To seal the waste disposal areas, vegetation and earth was removed and a liner was constructed.

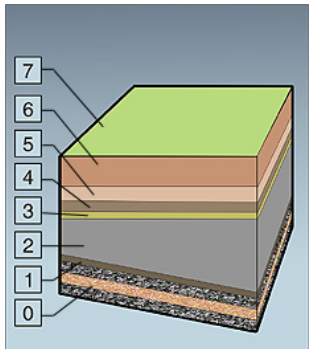
- The liner was constructed with metal mesh, concrete, and a layer of waterproof paint to seal the disposal cells

- Above the cap, layers of gravel and geotextile sheets separate different processes and allow for water and gas movement.

84.

85.

86.



87.

84-85. Drainage channels built to direct runoff water.

86. A storage pond where water rainwater collects away from the landfilll

87. A cap diagram showing the layers that separate waste from the ground's surface

Performances

EROSION

PREVENTS EROSION AND ENCOURAGES SOIL CREATION/CONSOLIDATION.

- This project prevents erosion and encourages soil create through a performance based planting

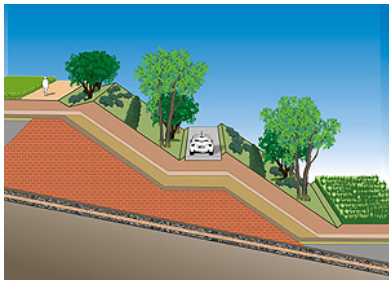
- The complex planting scheme chose species to cater to the unique microclimate conditions of the landfill terraces

- Three types of planting were used: crops, trees, and shrubs to correspond to different conditions

- Crops occupy the flat areas of the terraces to improve soil fertility, fix nitrogen and consolidate the soil

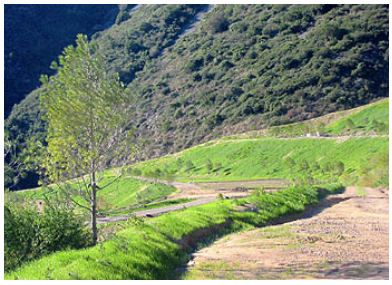
- Rows of pine trees line the drain channels and paths provide stability and wind breaks

- Native shrubs were chosen for the steep slopes that could propagated naturally and hold the soil of slope.

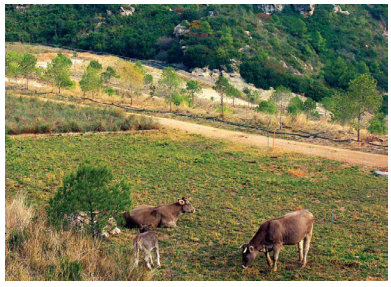


88.

89.



90.



91.

88. Planting to control erosion was organized in terraces of crops, paths, and the planting of grass and trees.

89. An overview of the final plantings of the Parc.

90. Pathways in between strips of lush landscape help cultivate the soil as well as make the Parc accessible to users.

91. Cows graze on portions of the flat landsape.

Performances

ENERGY

BIOGAS EXTRACTION AND COLLECTION

- The decomposition of waste generates biogass, which results from anaerobic decomposition.

- The gas is primarily methane (55%) and carbon dioxide (45%)

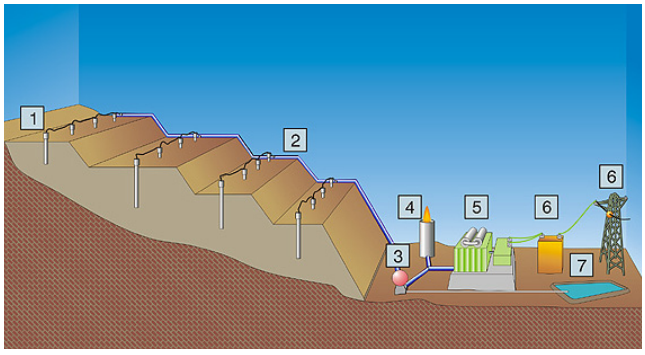
- To extract the biogass from the landfill a 10km network of pipes link 240 extraction wells to the on-site power plant

- The system is buried in the thickness of earth needed for restoration and is accessible via a set of inspection chambers.

- The gas is highly saturated with water,gravity is used to de-water the gas, the terrace grading and steep slopes help the system work efficiently.

92.

93.



94.

92.-93. Openings to allow excess gas to escape

94. Diagram of extraction and energy production.

Performances

ENERGY

[RENEWABLE ENERGY]

- The on-site power plant burns the biogas collected on-site

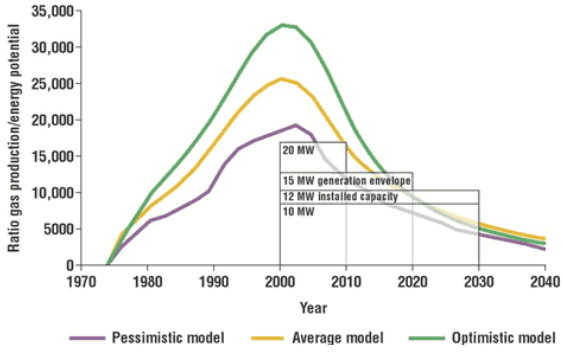
- The plant generates 100 kWh of power yearly, which is enough to power the entire public lighting system of the City of Barcelona

- Release of biogass would contribute to the greenhouse affect because methane is 21 times more effective as CO2 as a greenhouse gas

- By capturing 50 million m3 of methane annual, Garraf prevents 600,000 metric tons of CO2 being released to the atmosphere yearly.

- In addition, by generating 100 million kWh of renewable energy per year, Garraf saves 50,000-150,000 metric tons of CO2 that would otherwise be released by fossil-fuels

- In total, the landfill prevents 750,000 metric tons of CO2 from being emitted annual, the equivalent of 17,000 hectares of new forest, or taking 150,000 cars off the road.



95.

95. The graph shows the potential of energy production on the landfill site.

Performances

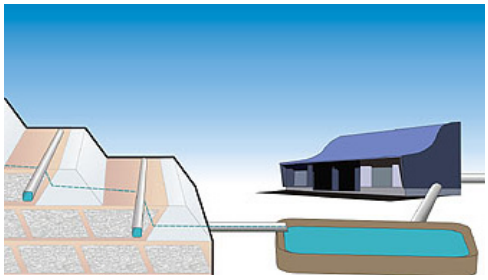
WATER QUALITY

(LEACHATE EXTRACTION]

- The anaaerobic decomposition of garbage generates liquid by-products called leachates

- At Garraf the leachates are collected and transported via a system trenches and pipes that collect the liquid within the landfill and deliver them to a storage and homogenization reservoir

- The leachates are then pumped to the treatment plant for the beginning of a complex treatment process



96.

97.

98.

96. Diagram of the process to extract the leachate from the site.

97. A retainer pool where the leachate is placed prior to treatment.

98. Leachate is collected in underground pipes and then pumped into the reservoirs.

Performances

WATER QUALITY

(WATER TREATMENT AND REUSE]

- The treatment process aims to reduce and extract pollutants in the leachate and create semi-clean water that can be reused for various purposes on site. In the first stage of treatment, the leachates go through two bioreactors and then in the second phase advanced filtration using membrane technologies

- In the first bioreactor, the leachates undergo biological activation to activate the micro organism that live in the leachates. These organisms are capable of transforming the pollutants of organic origin to inert matter. The second reactor, which is a closed reactor, transforms the ammonia (which is a polluting gas over 70mg/l) into nitrogen

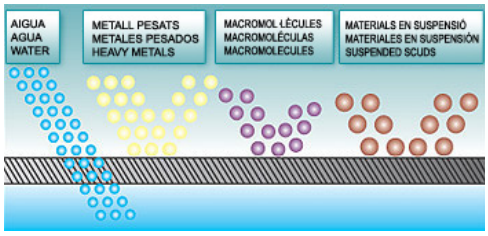
- A by-product of the 1st phase is sludge (biomass) that still has pollutants present. It goes through an ultrafiltration process that separates the biomass from water. Then it goes to a nanofiltration process: a tertiary treatment that removes very small particles like heavy metals. This water is reused on site for irrigation, fighting forest fires, and cooling the thermal engines.

- Treated water has a high salinity. The remaining treated water goes through reverse osmosis to reduce the salinity and make it viable for reuse.

- For every 100 liters of leachates treated, 70 liters becomes reusable clean water.

99.

100.



101.

99. The leachate treatment facility near on the site.

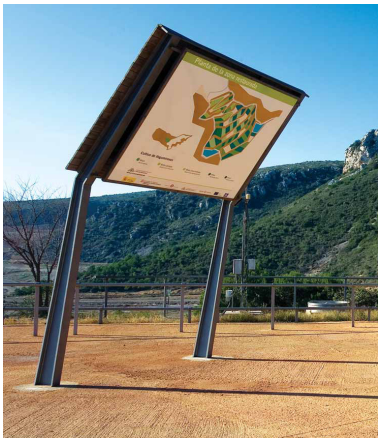
100. Mechanical components of the first bioreactor. All leachate water passes through here in the beginning of treatment.

101. Diagram of the nanofiltration process

Challenges

ACCESS AND PUBLIC PERCEPTION

- Viewpoints and information has been created to help educate the public better.



102.

103.

COST

- to clean the waste and restore the valley close to its original splendor needs considerable funds. This includes the continual maintenance costs.

104.

105.

102. Public information boards on the Parc Garref project.

103. Viewpoints have been created for the public to access.

104. Structures built using the waste from the landfill.

105. An overview of the park area that was restored.

Challenges

MAINTENANCE

- In order to ensure the proper growth of the species introduced and dispose of the necessary water during the process, an irrigation system has been installed for the whole of the restored area.

- Maintenance work that needs doing are the sealing and closure of the last working faces, the dismantling of disused equipment, the continuation of maintenance of the 20 restored hectares and the restoration of the remaining areas, the upkeep of pathways, ducts, ditches, irrigation channels, roads, view points and the Sentiu dry riverbed, compulsory over a period of 30 years.

106.

107.

106. Channels made for water displacement will need continual upkeep to ensure "clean" runoff stays separated from contaminated water.

107. Erosion control in the landscape. The grown plants will be watched and maintained around the pathways and roads.

CALIFORNIA ACADEMY OF SCIENCES

SAN FRANCISCO, CALIFORNIA

CALIFORNIA ACADEMY OF SCIENCES

SAN FRANCISCO, CALIFORNIA

SAN FRANCISCO CITY:

Area: 121 square kilometers (46.9 mi2)

Population: 805,235

PROJECT/RIVER DATA:

Designer: SWA

Cost: $488 million ($4.5 million landscape construction; $240,800 landscape fee)

Construction: completed 2008

Project size: 10 acres

Green roof size: 2.5 acres

before

after

The California Academy of Sciences, the "world's greenest museum," has earned LEED-Platinum certification through an ambitious vision for sustainable design. Landscape architecture played a major role in the realization of the design team's concept of "lifting up a piece of the park and putting a building under it," resulting in a sculptural 2.5-acre living roof that provides a unique interpretive experience for visitors (both inside and outside the building). The visibility of the green roof structure, it integration into the museum exhibit and research application, projects the highest level of sustainability.

Performances

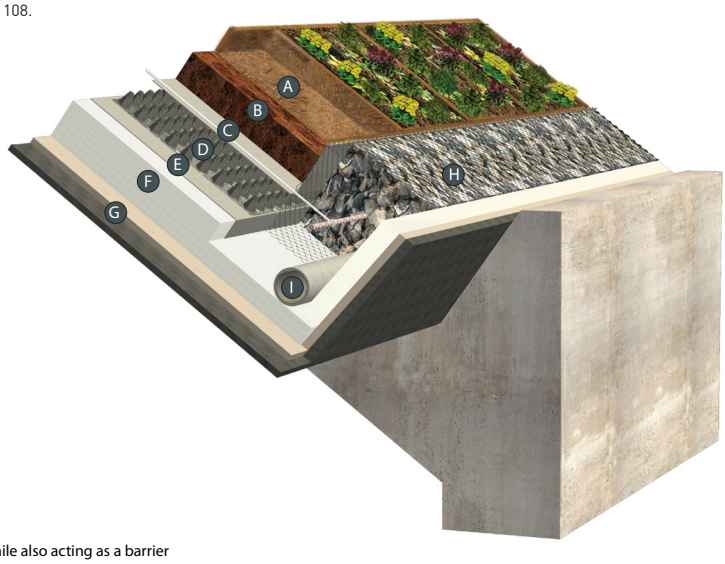
STORMWATER

EFFECTIVE IN CAPTURING STORMWATER.

- Absorbing 3.5 million gallons of rainwater each year, thus reducing the amount of stormwater runoff by 93%.

- Stormwater collected on the roof is recycled back into the water table.

108.



A. COCONUT FIBER TRAY
a 100% biodegradable tray holds the soil and young plant seedlings. The trays are made from the waste products generated by the coconut industry.

B. SOIL MIXTURE
Six inches of soil is laid beneath the coconut fiber trays, providing a substrate for plant roots to grow into as they become established.

C. FILTER
This polypropylene fabric filter helps contain the soil and keep it from washing away, while also acting as a barrier between the planted surface and the building insulation.

D. DRAINAGE TRAY
Made of strong lightweight plastic, the trays help in the regulation and drainage of rain/irrigation water that percolates through the soil and fabric filter.

E. PROTECTION LAYER
This thin material fabric (usually PVC vinyl) separates water and drainage runoff from the insulation layer and away from the structure of the roof.

F. INSULATION
The insulation works with the vegetation to keep the building interior roughly ten degrees cooler than a standard roof. It also lowers the noise frequency by forty decibels.

G. CONCRETE
The structural form work which makes up the buildings mounded roof.

H. GABION BASKETS
Filled with stone rip rap, the gabions provide structural support and aid in drainage.

I. IRRIGATION SYSTEM
The system of irrigation is computerized and regulated to provide extra water during periods of prolonged drought. Irrigation water comes from collections elsewhere within the park, rather than relying on the City.

108. Roof system

Performances

VENTILATION

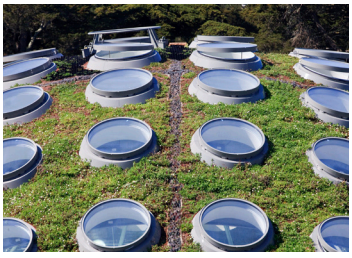
NATURAL VENTILATION IN THE BUILDING.

- The steep slopes of the roof creates a natural ventilation system, which funnels cool air into the open-air plaza on sunny days and vents hot air from the building through automated skylights.

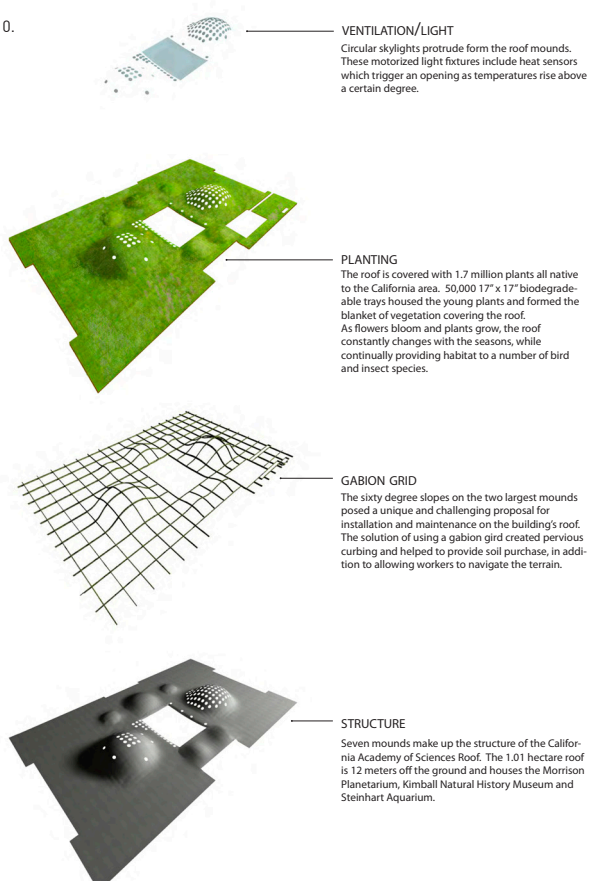
- The building interior is kept roughly 10°F cooler from the roof insulation and vegetation.

109.

111.



110.



109. Installation of the automated skylights

110. The form and materiality were designed to work together to naturally ventilate and insulate the building effectively.

111. Rising hot air is released through the automated skylights.

Performances

ENERGY

- Generates approximately 213,000 kilowatt-hours of energy per year and prevents the release of 405,000 pounds of greenhouse gas emission into the air through the installation of 60,000 photovoltaic cells that surround the living roof.

- 5% of the building's total energy is supplied through the photovoltaic cells installed in the perimeter canopy system of the roof.

112.

113.

112. Installation of PV cells.

113. PV cells form a shade structure for the building.

Performances

PUBLIC EDUCATION

- Provides interpretative and educational opportunities for more than 1.6 million visitors annually (the projected visitor count; the actual visitor count has far exceeded expectations).

114.

115.

114. The technology that went into the design of the green roof has now become part of the educational outreach.

115. A viewing platform allows the public to get up close to the green roof and watch it work.

WILDLIFE

IMPROVEMENTS IN WILDLIFE POPULATIONS.

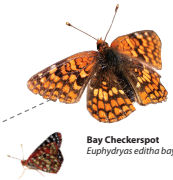
- The California native plants that carpet the building were chosen to select local butterflies, birds, and insects, some of them endangered.

116.

117.

Anna's Hummingbird
Calypte anna

118.



Bay Checkerspot
Euphydryas editha bayensis

Stonecrop
Sedum spathulifolium

Self Heal
Prunella vulgaris

California Plantain
Plantago erecta

Tidy Tips
Layia platyglossa

Beach Strawberry
Fragaria chiloensis

California Poppy
Eschscholiza californica

Miniature Lupine
Lupinus bicolor

Goldfield
Lasthenia californica

Sea Thrift
Armeria maritima

Water consumption (low / medium / high)
Light requirement (shade / part shade / sun)
Soil moisture (dry / moist)
Soil description (clay / sandy, well drained)

116-117. Native California plants grow on the roof.

118. Plants were chosen for their value in attracting different species of wildlife.

Performances

HEAT ISLAND MITIGATION

- There is anecdotal evidence of heat island mitigation of this project. However, this claim could be disputed, given that the green roof is located within a larger greenspace (Golden Gate Park) and not an urban area, where green roofs offer the most potential for heat island mitigation. Indeed, the presence of the building itself may worsen heat island effect by obstructing cool air movement from the ocean. There are no reports to confirm or deny either claim.

119.

120.

119. Green roofs have heat island mitigation potentials in urbanized areas.

120. The project may or may not have heat island mitigating effects.

Challenges

PUBLIC PRESSURE

- While the design intent is to remove irrigation systems and let the green roof run dry during the summer seasons (representative of a native California landscape) - the image of the green roof has become so iconic that the roof is still being maintained with irrigation during those months. The long-term vision is to remove the irrigation system.

- The removal of the irrigation systems could have unintended consequences, potentially increasing heat island effects and even increasing the temperature of the building itself.

- The use of irrigation on the green roof over time is still subject to debate.

COST

- Deemed a "high maintenance superstar," by writers such as Linda McIntyre (LAM), the roof is both celebrated and lamented for its high cost in time, money, and energy. While critics state that the cost is excessive and could have been used to implement a greater quantity of green roofs, McIntyre points out the difficulty of quantifying the success of a design that "captures the imaginations of millions of people," communicating that design and sustainability matters and inspiring dozens of new green designs as a result.

121.

124.

125.

121. The roof remains irrigated and green throughout the summer months.

124. Landscape construction costs for the entire project was $4.5 million.

125. Many argue the educational values of the project are worth the high construction costs.

Challenges

MAINTENANCE

- The roof is a living exhibit, accessible only through the elevator to the roof. Unfortunately, the maintenance crew has to use the same elevator – there is no storage capability for supplies on the roof.

- It remains to be seen how the roof will last over time. Most buildings require long-term weathering and re-waterproofing. In 40- or 60-year's time, what will be the procedure for updating and maintaining the roof and building, particularly one of innovative and unique construction?

122.

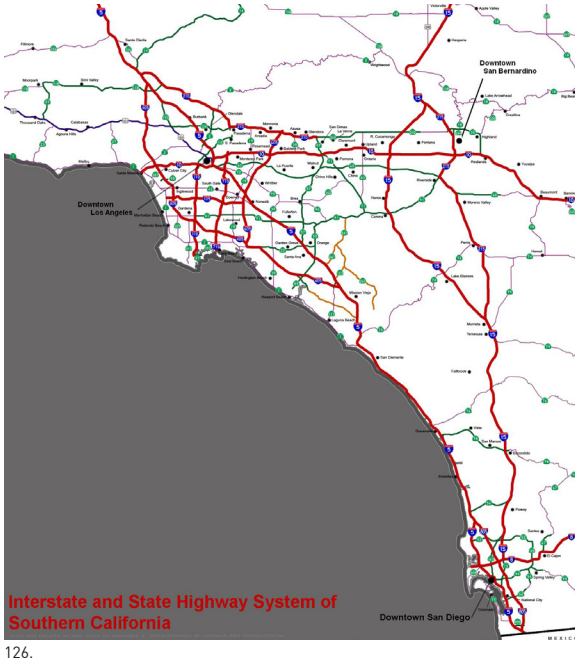
123.

122. Maintenance is a challenge for this project.

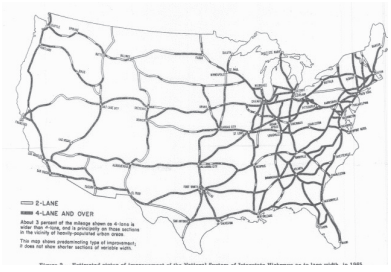
123. Accessibility to the roof is limited to one elevator.

PERFORMANCE POTENTIALS FOR LOS ANGELES FREEWAYS

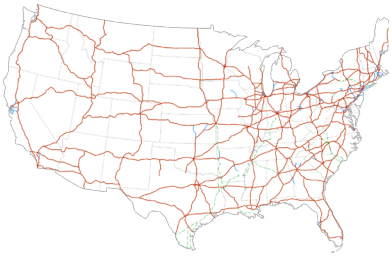
PERFORMANCE POTENTIALS FOR



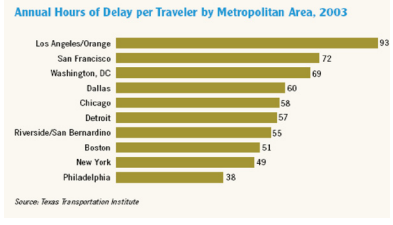
126.



128.



129.



127.

SOUTHERN CALIFORNIA FREEEWAYS

President Eisenhower pushed the country ahead with a comprehensive road program through the Interstate Highway System bill in 1956, impressed by Nazi Germany's efficient autobahns, built for efficient military defense movements. What resulted was a highway system 48,876 miles long (US Department of Transportation Federal Highway Administration), taking up approximately 1% of the area of the US (equivalent to the state of South Carolina) (National Cooperative Highway Research Program). Southern California's excitement over the interstate system has created an extensive web of

LOS ANGELES FREEWAYS

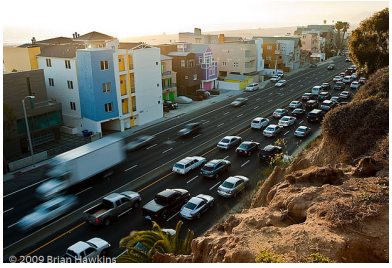

130.

132.

134.


131.


133.



135.

highways, currently 527 miles in Los Angeles County (Los Angeles Department of Transportation).
It is undisputable that highways have contributed greatly to economic progress in Los Angeles, and are the most-heavily relied upon method of transportation. However, this infrastructure has had less desirable outcomes as well. Los Angeles is the US capital of traffic jams, at 93 hours of delay annually per person (Texas Transportation Institute). Currently, the city is a non-attainment zone (meaning it persistently exceeds national ambient air quality standards) for ozone, carbon monoxide, and particulate matter (PM-10) (Environmental Protection Agency). With a projected population increase of 3.5 million by 2050 in Los Angeles County alone (Lin), reconsidering the single-use performances of highways in Los Angeles may soon be a necessity. This chapter focuses of performance potentials of Los Angeles freeways subjectively, citing potential applications from a variety of sources.

TRANSPORTATION CORRIDOR

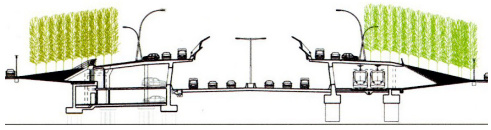
GRAN VIA

PROJECT DATA:
Designer: Arriola & Fiol arquitectes
Cost: 72 million Euros
Construction: 2002-2006

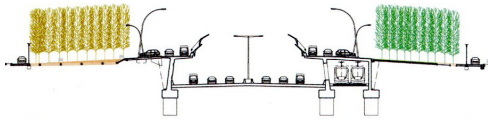
Los Angeles highways are simultaneously democratic (a one-size-fits-all for trucks, vans, cars, and motorcycles) and discriminatory (to a class of people who don't have the funds to support vehicle ownership). Although there are some notable exceptions (e.g. the I-105 has light rail integrated), Southern California highways are designed for private vehicles, and therefore privately-funded transportation. Access to this public amenity is limited to a certain class.

How can a transportation corridor be diversified? Is there a way to do this and make it more efficient and flexible? The Gran Via in Barcelona is a notable precedent for its activation of a single-use sunken freeway. This project carefully orchestrates uses, creating a sectionally-rich transportation corridor from an existing sunken freeway. With fast traffic in the central trunk, 3.5m cantilevers form lower-speed service roads, accomodating

136.



137.



138.

139.

126. (previous page) Southern California is a high-density mesh of highways.

127. The average Los Angeleno spends 93 hours a year delayed by traffic.

128-129. The projected layout of highways in 1965 is remarkably close to the highway system of today.

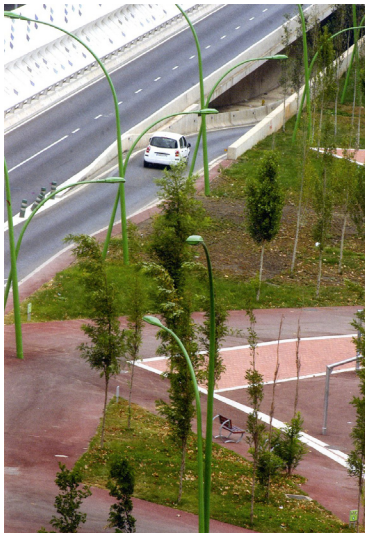
130-5. Images of SoCal freeways

[CONTINUED]

a tramline and parking below while reducing noise and air pollution exposure to nearby neighborhoods. Bridges were placed every 400m (3 blocks) for cross traffic. Custom-designed acoustic barriers arc over the central carriage way, cupping the infrastructure but not covering it entirely. The resulting inclined sections that connect service roads to neighborhood streets (20%) were turned into green spaces for public use (Kelly Shannon, Gran Via de les Corts Catalanes).

140.

141.



142.

136. The Gran Via attempts to transition neighborhood streets to a humming piece of infrastructure.

137-138. Sectionally-rich design incorporates many uses into the corridor.

139. Archig acoustic barriers mitigate noise pollution.

140. Opportunities for other forms of transportation were taken with the incorporation of a tramline.

141. Pedestrian access is enabled to the corridor.

142. Green spaces link service roads and neighborhood streets.

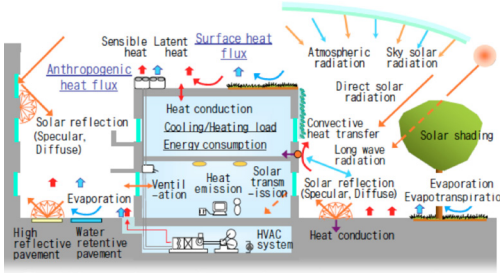
HEAT ISLAND MITIGATION

[LOS ANGELES]

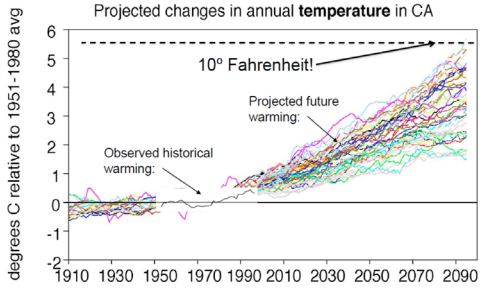
Urban heat island effect is measured as the temperature difference between the air within the urban canopy layer and that measured in rural areas. This phenomena is mainly caused the absorption of solar radiation by urban surfaces, and the subsequent trapping of the heat-energy by the geometries of built environments.

Borne of the urban condition, urban heat island even more complex impacts, from precipitating the formation of smog (as temperature rises) to creating scenarios that encourage huge consumptions of energy (e.g. air conditioners during a heat island-induced heat wave). Mitigating these impacts is just as complex. However, as Alex Robinson argues in his research for SWA, "high density cities may be our best sustainable model and so making them comfortable can have some of the largest ecological/sustainable impacts." (Robinson, Urban Heat Island Countermeasures Summary & White Paper).

Los Angeles is currently posed for worsening heat island effects. Projected temperature rises from global warming will make Los Angeles hotter regardless of heat island effect (Robinson, Urban Heat Island Countermeasures Summary & White Paper). With a growing population, the increased development and mineralization of the urban environment seems inevitable. The presented research focuses of facilitated air movement and surface modification as urban heat mitigation techniques.



143.



144.

145.

143. An example of a diagram showing what criteria is considered in urban heat simulation models.

144. The results of fifteen models simulating three different CO2 scenarios in California.

145. Irrigated orchards in Los Angeles brought down summer temperatures, an example of past human-moderated temperature.

Performances

HEAT ISLAND MITIGATION

(AIR MOVEMENT, STUTTGART, GERMANY)

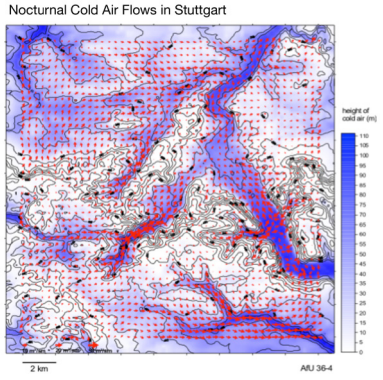
Built urban environments can suppress air movements, obstructing cool flows and exacerbating pollution.

The city of Stuttgart in Germany provides an excellent precedent for designing for air movement. The city's Urban Climatology department has identified areas critical for nocturnal air flows, called "STEP" zones. Cold-air generators (e.g. agricultural fields, forests, oceans) and flow corridors are identified and protected from development, so cool air can flow into the otherwise poorly ventilated city at night. Corridors must be at least 100m wide and kept free of obstructions (including trees) (Robinson, Urban Heat Island Countermeasures Summary & White Paper).

Many reports provided in Alexander Robinson's research for SWA recommend wider streets and stepped back buildings to improve air circulation. Depending on urban geometry, freeways have the potential to act as corridors for cool-air movement. Perhaps freeways can be enlisted in moving cool air from the Pacific Ocean through dense urban neighborhoods in Los Angeles.

146.

147.



148.

146. A STEP zone corridor in Stuttgart.

147. Cool air flows are prioritized in design.

148. Stuttgart's Urban Climatology department maps nocturnal air flows in the city to optimize urban air movement.

HEAT ISLAND MITIGATION

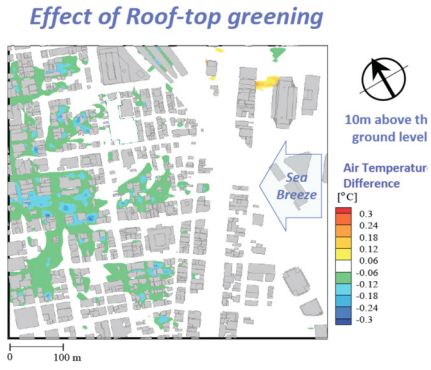
SURFACE MODIFICATION

Surface modification, in the form of rooftop greening, also has the potential to mitigate heat islands in Los Angeles. The temperature in Los Angeles was moderated once before with surface modification: the agricultural irrigation of orchards drastically dropped summer temperatures (Heat Island Group). Low-water landscapes or xeriscaping has the potential to increase urban heat island in Los Angeles, creating landscapes that go dormant in the summer instead of absorbing solar radiation.

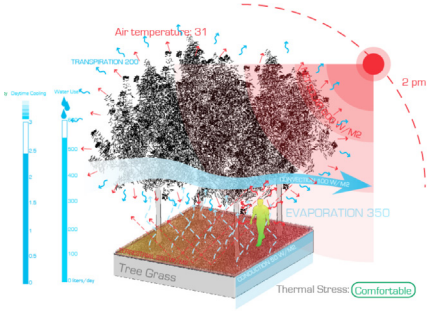
The most water-efficient method of surface modification are trees, which produce deep shade and comfortable microclimates (Robinson, Urban Heat Island Countermeasures Summary & White Paper).

Through analysis, Los Angeles freeways present the opportunity to create strategically placed swaths of porous, evapo-transpiring surfaces on top of freeways to mitigate urban heat island effect.

149.



150.



151.

149. Projects like the Hollywood Cap Park could be optimized for both public access and urban heat mitigation.

150. This study based in Tokyo shows the temperature changes as a result of projected rooftop greening.

151. Trees are bery good at creating comfortable microclimates. They are also water-efficient vegetation for heat island mitigation.

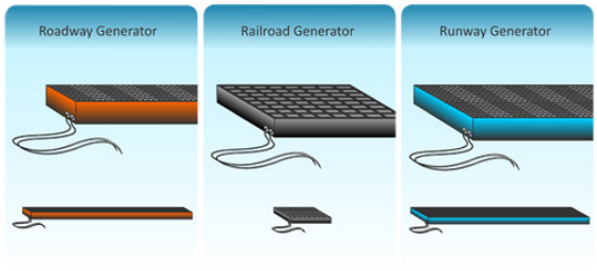
Performances

ENERGY

PIEZOELECTRIC

Within the public realm, alternative energy production is well-understood and embraced as sustainable. It is a concept easily communicated in terms of costs and benefits, especially in comparison to issues like urban heat islands.

Piezoelectric highway infrastructure converts the vibrations caused by driving vehicles into electricity. Mike Gatto, a state assembly member, is trying to pass a bill that would authorize Cal Trans to implement piezoelectric technology in California freeways. These piezoelectric sensors would be installed under the road. Mike Gatto's office claims that Israel and Italy have already started using this technology, and that a single-lane, one kilometer stretch of roadway could power 30,800 homes per year (Romero). A request to Mike Gatto's office via email for data and further information went unanswered.



152.

153.

152. Examples of piezoelectric sensors.

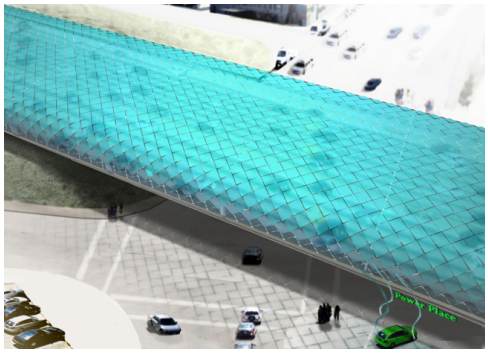
153. Mike Gatoo, a California state assembly member, is pushing for legislation that would allow installation of piezoelectric sensors.

ENERGY

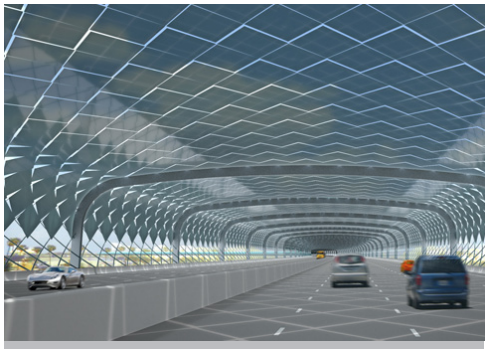
PV SHADE STRUCTURES

Swedish architect Mans Tham's proposal for the I-10 in Los Angeles is a shade structure for drivers. Along this East-West oriented stretch of freeway Tham proposes 237 acres of solar panels to the freeway infrastructure for energy production. Estimates by Tham were not in correct units for electricity ("150MW " instead of MWh), so an accurate idea of how much would be produced can not be determined. His proposal also claims to reduce freeway noise (Michler).

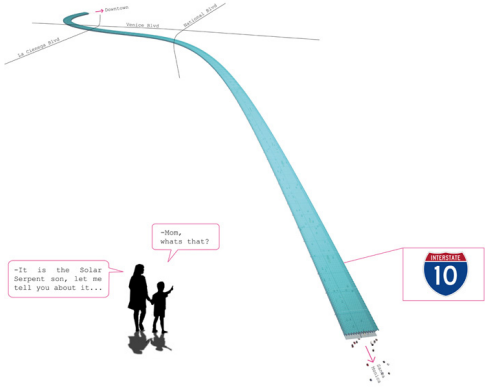
This kind of forward thinking design could face serious public resistance. PV structures already have a reputation for looking unsightly, and the crux of Tham design relies upon the structure appearing to look like a serpent. But, from what vantage point would people see the freeway to experience it appearing like a serpent? And would Los Angeles citizens seriously consider capping the most popular freeway to the beaches?



154.



155.



156.

154. Swedish architect, Mans Tham designed a Photovoltaic (PV) structure, meant to imitate a serpent's skin.

155. The PV panels would provide shade to drivers, a benefit for this East-West oriented freeway.

156. Tham's anticipation of public acceptance may be overlly optimistic.

ENERGY

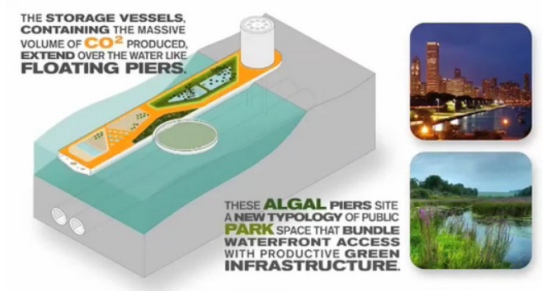
BIOFUEL

Port architects, the finalist of WPA 2.0 (a competition organized by UCLA's cityLAB), proposes capturing and funneling CO_2 from vehicle tunnels under large water bodies into an industrial-scale algae bioreactor. Algae would use the CO_2 to grow, and would then be harvested for biofuel and fertilizer.

This technology may not yet be available for application in Los Angeles. In their presentation, Port lists 17 cities that have existing infrastructure eligible for this concept, and Los Angeles was not included.

157.

158.



159.

157. Port architects proposed a floating pier that harvests algae for biofuel production.

158. The project concept requires a sealed, long highway.

159. Algae is grown along floating piers.

ENERGY

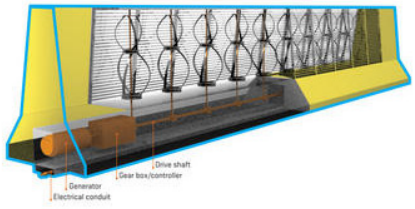
WIND TURBINES

Several popular student designs have proposed alternative energy generation through the installation of wind turbines alongside highways, to take advantage of the turbulence produced by cars.

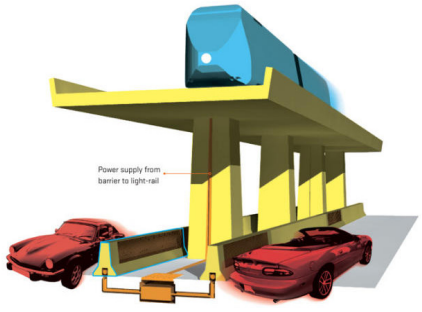
Mark Oberholzer proposed wind-turbines in traffic dividers, which would exploit the turbulence from both sides of traffic for energy generation. His design routed energy to a light rail train directly above the traffic divider, although he did not have calculations to prove enough electricity would be generated for this use (Cavanaugh).

Another student placed two large wind turbines horizontally above traffic, on the same steel frames highway signs use. This design was calculated to produce 9,600kWh per year (Chapa).

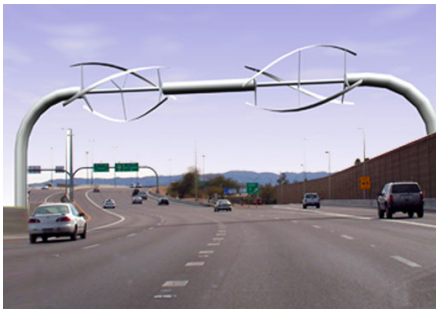
In a city known for its traffic jams, this kind of design would have to be implemented carefully to make sure enough turbulence is produced to push the turbines.



160.



161.



162.

160. Mark Oberholzer's design installs wind turbines in traffic dividers.

161. Energy produced by turbulence from passing cars is proposed to run a light rail train.

162. Another design places turbines horizontally.

WILDLIFE CROSSINGS

Although more relevant in less developed areas of California, wildlife crossings provide opportunities for animals to safely cross roadways that otherwise fragment habitats and isolate animal populations. With an estimated 1.5 million deer killed annually on US roads (Forman 118), and potentially a greater biomass of smaller animals killed (Forman 115), wildlife crossings reconnect remaining land patches to facilitate healthy metapopulation functioning. The emerging science of Road Ecology in the US has studied wildlife connectors, and claims that the combined use of fencing and wildlife connectors is the most effective structural method to guide safe passage for wildlife and reduce roadkill.

In Southern California, studies show that drainage culverts are regularly used by wildlife (Sandra J. Ng). San Bernandino already has specially designed underpasses for bobcats, coyotes, and deer. An overpass is currently being planned for antelope (California Issues Solicitation for Wildlife Crossing Construction Services).

However, once a road has been built, it severs an entire ecological system, disrupting hydrology and established habitats through a variety of effects, including pollution, facilitating invasive plant species movement, dividing and isolating animal populations, changing species composition, and traffic noise (Tanner, Forman). By no means do wildlife crossings mitigate the disturbance a highway has on an ecosystem.

163.

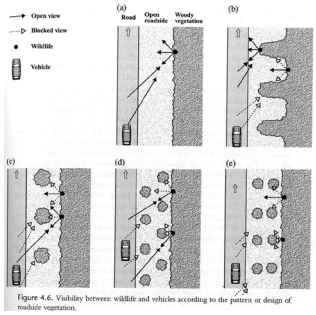


Figure 4.6. Visibility between wildlife and vehicles according to the patterns or design of roadside vegetation.

164.

165.

163. A wildlife connector in the Banff National Park, Canada

164. Visibility between wildlife and vehicles can affect both driver and animal safety.

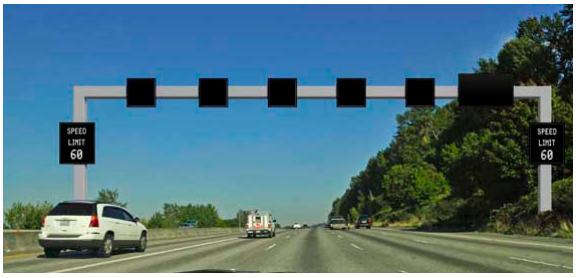
165. Box culverts under the I-5 in California are used by wildlife.

REAL-TIME VARIABLE SIGNAGE

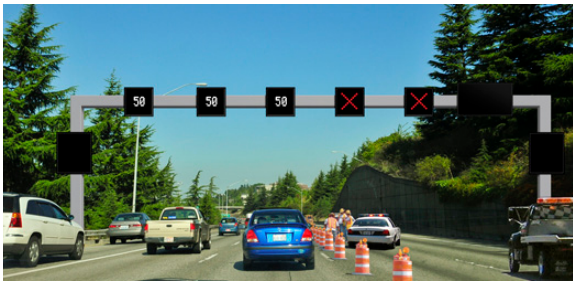
I-5 FREEWAY, OREGON

The Washington State Department has initiated the Smarter Highways program, which consists of a set of real-time variable signs controlled by computers. Traffic sensors have been installed along the I-5 in parts of Washington state. These sensors collect traffic data, which is then analyzed by computers. LED signs are controlled by these computers, which changes speed limits, lane access, and provides other messages.

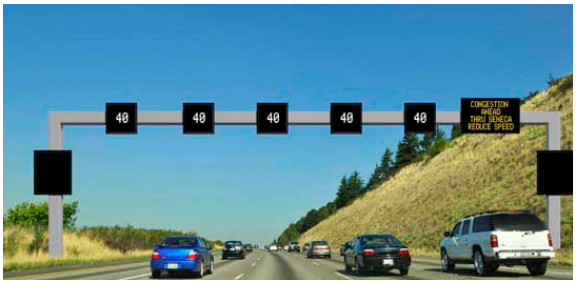
By warning drivers of changing traffic conditions up road, this system hopes to make traffic more efficient. An ideal situation for the use of this technology would be approaching traffic slows down and passes through problem areas at a slower but more consistent speed, instead of stopping and starting. By giving drivers time to react to changing road conditions, this program could also reduce the probability of accidents (Washington State Department of Transportation).



166.



167.



168.

169.

166. A rendering of normal traffic conditions, the signs are blank and road speed limits are followed.

167. An example of signage during a blocking incident. Speed limits increase to bring traffic to normal speed.

168. Speed limits reduce as traffic gets heavier.

169. Signage options.

ALTERNATIVE MATERIALS

QUEIT PAVEMENT

The EPA defines noise pollution as “unwanted or disturbing sound.” Noise pollution has real effects on human health, and has been linked to stress-related illness, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity (Environmental Protection Agency).

European countries have led the way on developing quiet pavements and implementing them in urban and rural areas. Denmark, the Netherlands, France, Italy, and the United Kingdom have all implemented quiet pavements in their roadways. Quiet pavement is part of a wholistic approach to noise reduction in these countries, including noise policies and multiple mitigation strategies.

In urban areas, thin-surfaced, negatively textured gap-graded asphalt mixes are used. Thin, gap-graded hot-mix asphalt (HMA) can reduce noise levels by 6 decibels (US Department of Transportation Federal Highway Administration).

Maintenance of porous pavement systems usually requires high-pressure water blasts followed by a vacuum to remove fluids and solids. Wastewater is then filtered and recycled for future applications (International Highway Transportation Outreach).

170.

171.

170. A double-layer porous asphalt pavement in Copenhagen, Denmark.

171. Semi-annual cleaning is required with high-pressure water blasts.

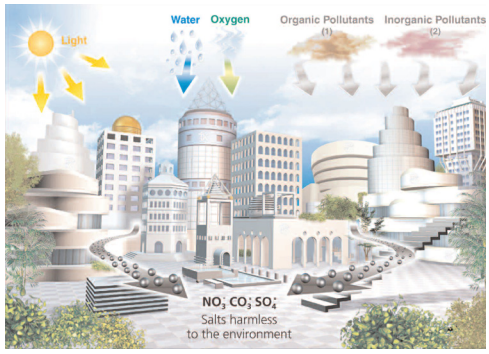
ALTERNATIVE MATERIALS

PHOTOCATALYTIC CEMENT

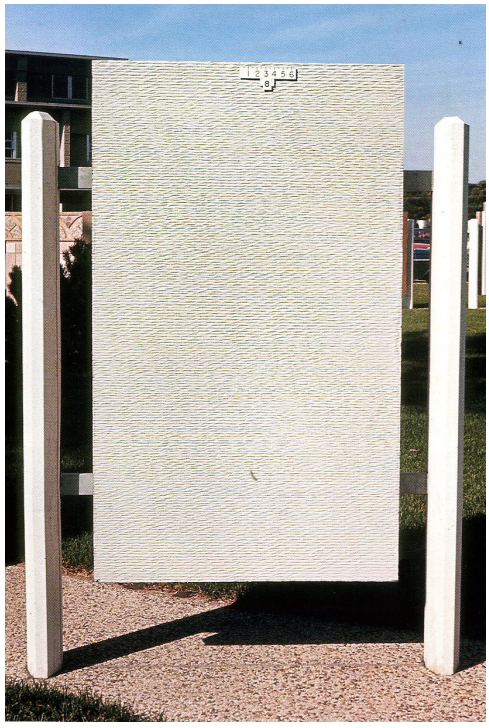
Photocatalytic cement reduces organic and inorganic pollutants in the air by converting pollutants that come into contact with its surface into innocuous salts. Pollutants affected include nitric oxide, sulfur dioxide, and carbon monoxide, a pollutant of particular concern in Los Angeles, which is a non-attainment area for carbon monoxide.

Researchers have calculated that covering 15% of visible urban surfaces in large cities could reduce air pollution by 50%.

This technology has already been employed in Japan, and has been used to create self-cleaning lamps, car coatings, construction materials, and air purifiers (Liat Margolis).



172.


173.

172. Dreams of a photocatalytic city.

173. The cement comes in grey and white.

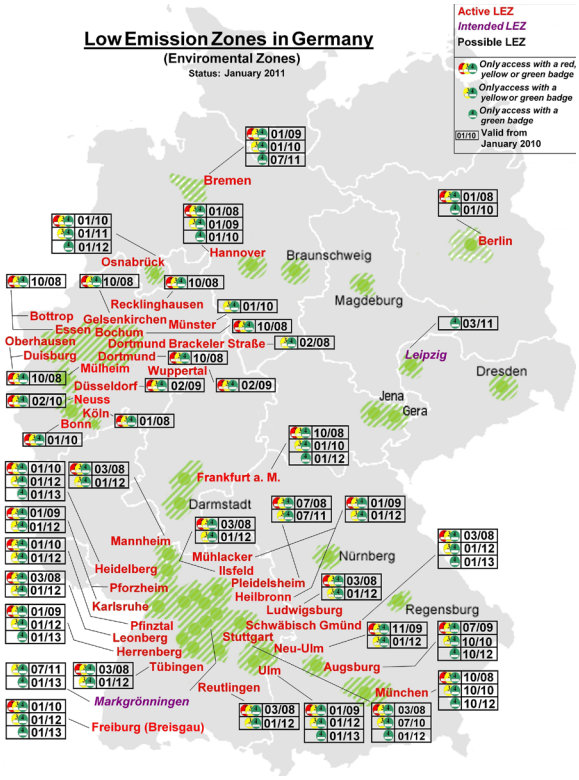
POLICY

REDUCED VEHICULAR USE

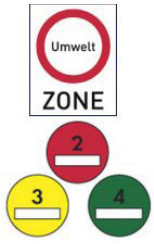
Unfortunately, landscape architects cannot make highways sustainable through only structural means. The most effective way to reach sustainability is through prevention, not clean-up.

In Germany, a 2006 anti-air pollution law was passed after Germany failed to meet EU pollution standards for fine particulates. This law necessitated restrictions of vehicular use in urban areas. Now, all drivers in Germany must have a special environmental sticker (Umweltplakette) on their car in order to enter low emission zones in cities.

There are three different colored emission stickers. Green means a vehicle meets the highest environmental standards, yellow is for less compliant cars, and red is the lowest level. Soon, cities will phase in policy that only allows green-stickered vehicles access to green zones (The German Way).



174.



175.

174. Low emission zones are presently being enforced in Germany

175. Signage and stickers for this new law.

POLICY

MINIMIZE FOOTPRINT

In the US, generous established standards for highway dimensions, designed by traffic engineers over several decades, are difficult to change locally because of a fear of lawsuits. This has led to mega-infrastructural cuts through landscapes, amplifying the magnitude of its environmental impact (Pincetl).

The Dutch are probably the most accomplished in road ecology through the work of individuals like H.D. van Bohemen and H. Bekker. Through a system of "no-net loss," the Dutch have attempted to minimize the loss of natural processes and biodiversity during highway construction. They have found that compensation costs are often marginal compared to total project costs, and these compensations may play a valuable role in the development of alternative route alignments (Forman 18).

Highway projects in France, such as the A29 Normandy Highway, are also designed with a minimized footprint for reduced environmental impact (Shannon).

176.

177.

178.

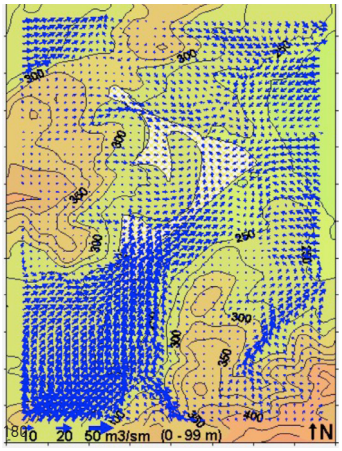
176. The I-405 freeway in California imposes a wide footprint on the landscape.

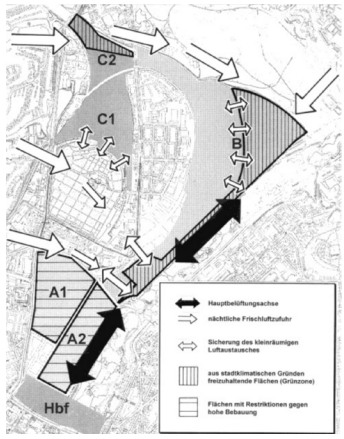
177. - 178. The A29 Normandy Highway in France was designed with a minimized footprint.

POLICY

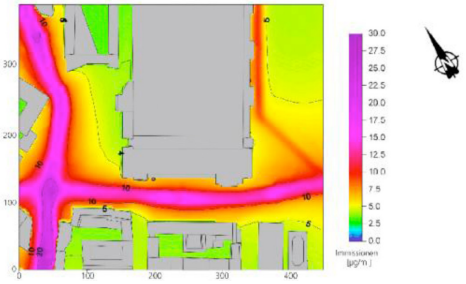
CLIMATOLOGY ANALYSIS

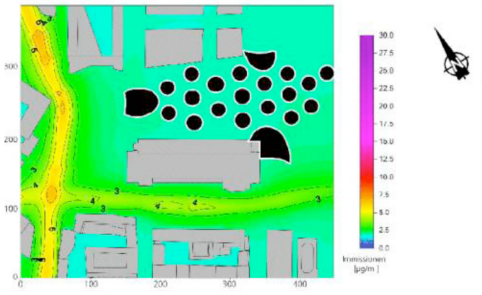
Because of poor ventilation, the city of Stuttgart carefully plans and conducts climatology analysis on large projects before they are constructed. This is particularly important in Stuttgart to maintain nocturnal air flows into the city to mitigate urban heat island, but other recommendations include: program placement relative to air pollution streams and noises, placement of pollution sources, orientation of buildings based on microclimatic comfort modeling, and expanding the main airflow axis (Robinson, Urban Heat Island Countermeasures Summary & White Paper 25).





181.





179.

179. Modeling of pollutant levels as a result of a project.

180. Cold air flows in Sttugart's inner city.

181. Urban climatology notes for the planning of a new project.

POLICY

ELECTRIC VEHICLE INFRASTRUCTURE

In an effort to support electric vehicle ownership, Washington state is implementing a network of public access EV recharging locations on I-5. The state has partnered with private companies to install fast-charging stations every 40-60 miles.

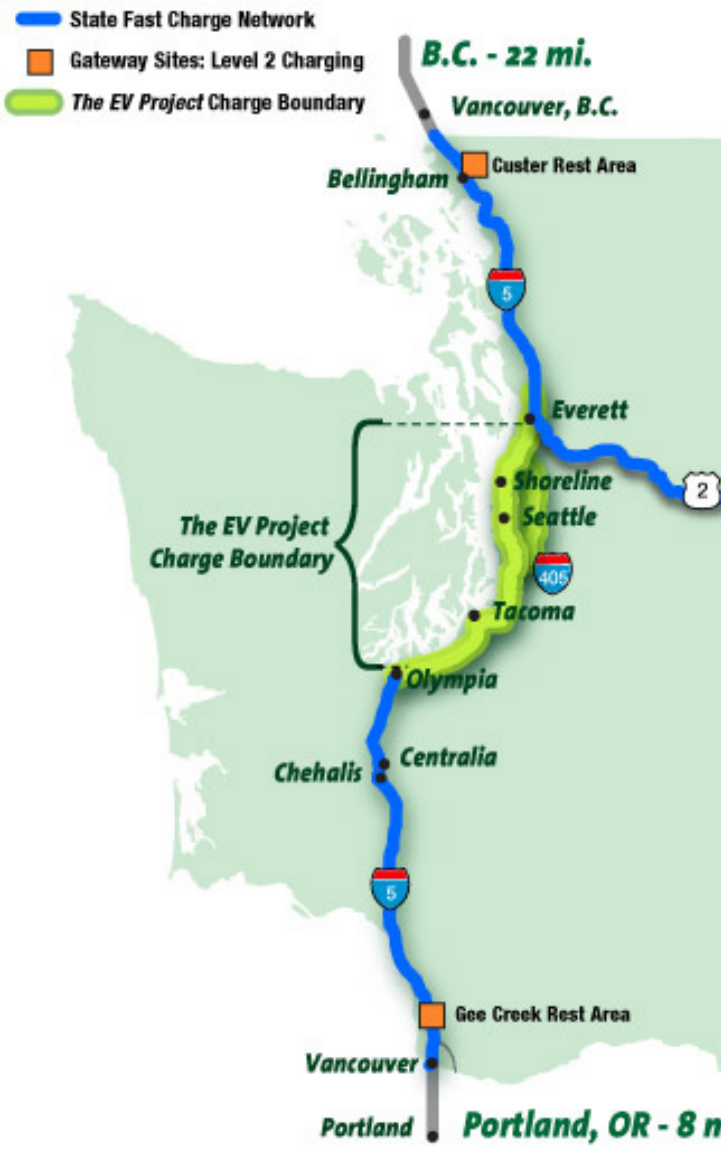
There are two charge options for consumers. The fastest charge will bring a battery for 0 to full in 20-30 minutes. A lower-cost option takes 4 to 8 hours, and will be located near private retail and travel centers.

Price for charging has yet to be established. Operating stations are expected by November 30, 2011 (West Coast Green Highway Initiative).

182.

182. A prototype EV charging 'pump'.

183. The EV project hopes to encourage individuals and businesses to buy plug-in electric vehicles.


State Fast Charge Network
Gateway Sites: Level 2 Charging
The EV Project Charge Boundary
B.C. - 22 mi.
Vancouver, B.C.
Bellingham
Custer Rest Area
5
Everett
2
Shoreline
Seattle
The EV Project
Charge Boundary
405
Tacoma
Olympia
Chehalis
Centralia
5
Gee Creek Rest Area
Vancouver
Portland
Portland, OR - 8 n

183.

CONCLUSION AND BIBLIOGRAPHY

CONCLUSION

This document is considered a "living document," and so is by no means finished. It is meant to be a continuously growing and evolving body of knowledge.

Part of the research of this initiative is keeping up to date with the status of covered projects. The evolution of the restoration of the Besòs, Cheonggeycheon, and Buffalo Bayou Promenade should be checked up on every few years to make sure the information presented here is relevant and up-to-date. In particular, are flood conveyance parameters still maintained? Have there been any changes in nearby development or public perception of the sites? How has water quality changed, and has this precipitated any changes in the rivers use? What consequences has global warming had on these river systems?

Keeping a tab of how the California Academy of Sciences green roof performs over time should also be considered, as well as comparing the number of people visiting it yearly and whether public perception of the installation has changed.

Staying up to date with highway design in European countries should also be a priority, especially in countries like Germany and the Netherlands, where politically-powerful green parties prioritize careful highway design. The emerging science of Road Ecology should also be monitored, for its relevance for highway design in less developed areas of California as well as its potential expansion into urban considerations.

Stormwater management in highway design is a subject worth further investigation, as my research for this topic was not very fruitful.

There are a few projects that were in design or construction phases when this research was conducted, and may be worth studying after completion. These projects include the Parque de la Gavia in Madrid by Toyo Ito, which utilizes a unique fractal-shaped, open-water treatment system. Route 73 in Sweden (the previous "Road of Death," renamed the "Road of Possibilities" in its new design) could also provide useful techniques for ecologically-conscious road design.

What my research has made apparent, however, is the limited impact landscape architecture professionals can make in isolation. The ongoing discourse about landscape infrastructure is valuable to have in both the academic and professional world, but inviting and including transportation officials and engineers in this design discussion is particularly relevant considering their current authority in infrastructure, especially in the eyes of the public. Taking engineers to task for generous highway standards that unnecessarily destroy habitat, for instance, could be a productive function for IRIS research, potentially creating change on a policy level.

BIBLIOGRAPHY

"A City and Its Stream: The Cheonggyecheon Restoration Project." Book. Harvard University Graduate School of Design, 2010.
Arriola & Fiol arquitectes. "Multilevel Infrastructure." Arriola & Fiol arquitectes. 25 07 2011 <www.arriolafio.com>.
Byung Hyuk Kwon, Jun Sang Park, Don Su Kim, Kwang Ho Kim. "Thermal Environment in a Street Canyon After Restoration of an Inner-City Stream." The Seventh International Conference on Urban Climate. Yokohama, 2009.
"California Issues Solicitation for Wildlife Crossing Construction Services." Targeted News Service 28 March 2011.
California Roadkill Observation System. 28 07 2011 <http://www.wildlifecrossing.net/california/gallery?tid=4>.
Cervero, Chang Deok Kang and Robert. "From Elevated Freeway to Urban Greenway: Land Value Impacts of the CGC Project in Seoul, Korea." Urban Studies 46.13 (2009): 2771-2794.
Chapa, Jorge. Student Design Turns Highways into Wind Farms. 30 04 2007. 02 08 2011 <http://inhabitat.com/student-designs-highway-power/>.
Chin, Yangkyo. "Cheonggyecheon: Revitalization of an Urban River." Topos: the international review or landscape architecture and urban design 55 (2006): 40-44.
Dolwick, Pat. "Re: (177151936) AirTrends Web Comments." Environmental Protection Agency. Lily Kerrigan. 29 06 2011.
Environmental Protection Agency. Data. Houston, New York, Los Angeles, Chicago, 07 07 2011.
—. Particulate Matter (PM-10) Information. 26 07 2011 <http://www.epa.gov/oaqps001/greenbk/pindex.html>.
Forman, Richard T.T. Road Ecology: Science and Solutions. Washington DC: Island Press, 2003.
Heat Island Group. L.A. Island. 21 June 1999. 01 08 2011 <http://heatisland.lbl.gov/learn/LAIsland/>.
Hirofumi Sugawara, Ken-ichi Narita, Min Sik Kim. "Cooling Effect by Urban River." The Seventh International Conference on Urban Climate. Yokohama, 2009.
Honey-Roses, Jordi. "Restoration of the Besos River in Barcelona, Spain." Academic Essay. 2007.
International Highway Transportation Outreach. Chapter Two: Maintenance of Quiet Pavements Systems in Europe. 04 08 2011 <http://international.fhwa.dot.gov/quiet_pav/chapter_two_f.cfm>.
Kee Yeon Hwang, Seungjae Lee. "Restore Cheonggye Stream in the Downtown of Seoul: Impacts of a serious Loss of Road Capacity on Traffic Conditions and Travel Behavior." 2004.
Kelly Shannon, Marcel Smets. "Gran Via de les Corts Catalanes." The Landscape of Contemporary Infrastructure. Rotterdam: NAi Publishers, 2010. 100-101.
Kwon, Kie-Wook. Ecological Change and Restoration Effect of Cheonggyecheon (Stream). Ed. Kie-Wook Kwon. Seoul, July 2011.
La reforma urbanistica del besos = The Besos Planning Reform. Barcelona: Actar D, n.d.

[BIBLIOGRAPHY CONTINUED]

Les Zones humides. 21 07 2011 <http://www.diba.cat/parcsn/parcs/plana.asp?parc=15&m=285>.
Liat Margolis, Alexander Robinson. Living Systems. Basel: Birkhauser, 2010.
Lin, Maria L. La Ganga and Sara. "60 million Californians by midcentury." Los Angeles Times 10 07 2007.
Los Angeles Department of Transportation. The City of Los Angeles Transportation Profile 2009. City Report. Los Angeles, 2009.
Los Angeles River Revitalization Master Plan. Master Plan. Los Angeles: Department of Public Works, 2007.
Martin-Vide, J.P. "Restoration of an urban river in Barcelona, Spain." Environmental Engineering and Policy (2001): 113-119.
Michler, Andrew. Crazy Awesome Solar Serpent Structure Proposed for Santa Monica Freeway. 21 05 2011. 01 08 2011 <http://inhabitat.com/massive-solar-serpent-winds-along-the-santa-monica-freeway>.
Montlleo, Antoni Alarcon and Marc. "Environmental Restoration of the Besos River." n.d.
Montlleo, Marc. Interview. Lily Kerrigan. 21 07 2011.
National Cooperative Highway Research Program. NCHRP Systhesis 305: Interaction Between Roadways and Wildlife Ecology. Washington DC, 2002.
Park Kil-Dong, Seoul Metropolitan Government, Korea. "Cheonggyecheon Restoration Project." n.d.
Pincetl, Dr. Stephanie. Interview. Lily Kerrigan. 29 07 2011.
Preservenet. Seoul Huts on Cheongye. Seoul, 9 June 2011.
Regional, Barcelona. "Text angles." 2002.
Revkin, Andrew C. "Cities Peel Back Pavement to Expose Watery Havens." New York Times 17 July 2009: 4.
Rieder, Max. "The Gran Via in Barcelona." Topos: the international review of landscape architecture and design (2005): 97-97.
Riu Besòs mendrisio anglès.pdf.
Robinson, Alexander. "Modulating Infrastructual Flows to Create Open Space." Landscape Infrastructure: Case Studies by SWA. Ed. Ying-Yu Hung Gerdo Aquino. Basel: Birkhauser, 2010. 30-35.
—. "Urban Heat Island Countermeasures Summary & White Paper." Patrick Curran SWA Fellowship. 2010.
Romero, Dennis. "Green Electricity From Freeway Vibrations? L.A. State Assemblyman Mike Gatto Wants to Make it Happen." LA Weekly 02 06 2011.
Sandra J. Ng, Jim W. Dole, Raymond M. Sauvajot, Seth P.D. Riley, Thomas J. Valone. "Use of highway undercrossings by wildlife in southern California." Study. 2001.
Sang-Hun, Choe. "Ambitious Rivers Project Meets a Sea of Opposition." New York Times 14 December 2009.
Seoul Metropolitan Facilities Management Corporation. About CGC: Water Supply. 28 June 2011 <http://english.sisul.or.kr/grobal/cheonggye/eng/WebContent/index.html>.
—. The Official Cheong Gye Cheon River Site. 09 06 2011 <http://english.sisul.or.kr/global/cheonggye/eng/WebContent/index.html>.
Singh, Timon. Piezoelectric Energy-Generating Roads Proposed for California. 14 02 2011. 02 08 2011 <http://inhabitat.com/piezoelectric-energy-generating-roads-proposed-for-california/>.
Sintesis de cifras de la ciudad de Barcelona. 20 07 2011 <http://www.bcn.es/estadistica/angles/dades/sintesi/

(BIBLIOGRAPHY CONTINUED)

images/sintesi1.pdf>.
Tanner, Dawn Renee. “Road to the Future: Strategies for Wildlife Crossings and Youth Empowerment to Improve Wildlife Habitat in Roaded Landscapes.” Dissertation. 2010.
The German Way. Driving: Environmental Zones in Germany. 01 08 2011 <www.german-way-com/driving-environmental-zones.html>.
U.S. Environmental Protection Agency. Particulate Matter. 24 06 2011 <http://www.epa.gov/air/particulepollution/>.
US Department of Transportation Federal Highway Administration. Frequently Asked Questions. 26 07 2011 <http://www.fhwa.dot.gov/interstate/faq.htm#question3>.
—. “Quiet Pavements: Lessons Learned from Europe.” FOCUS April 2005: Publication Number: FHWA-HRT-05-025.
Washington State Department of Transportation. Smarter Highways. 03 08 2011 <http://www.wsdot.wa.gov/smarterhighways/symbols.htm>.
West Coast Green Highway Initiative. Electric Highways Project. 04 08 2011 <http://westcoastgreenhighway.com/electrichighways.htm>.
Western Transportation Institute. Road Ecology. 04 08 2011 <http://www.westerntransportationinstitute.org/research/roadecology/default.aspx>.
Wikipedia. Dwight D. Eisenhower. 25 07 2011 <http://en.wikipedia.org/wiki/Dwight_D._Eisenhower#Interstate_Highway_System>.
—. Nazi Architecture. 25 07 2011 <http://upload.wikimedia.org/wikipedia/commons/b/bc/German_Autobahn_1936_1939.jpg>.