Designs for Coastal Security: Structural and Non-Structural Protections for the Houston–Galveston Region

As the hurricane of 1900 that destroyed the City of Galveston, more recent Hurricane Ike, and innumerable other storms have shown the Houston–Galveston region is particularly vulnerable to extreme weather events. Approximately one million people live within the region's current hurricane evacuation zones and by 2035 an additional 700,000 people are expected to move into these high-risk areas.

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Increasingly, major industrial sites are also being built in harm's way. The most important example of the growing risk to industry is the Houston Ship Channel. The Ship Channel includes the nations second largest port and its most important collection of petrochemical plants. It is the pulsating heart of a vast network of pipelines linking interdependent refineries and processing plants from New Orleans, Louisiana to Corpus Christy, Texas. This network fuels the nation. Its inundation would have immediate consequences for the national economy.

In 2007, the SSPEED Center (Severe Storm Prediction, Education, and Evacuation from Disasters) at Rice University was formed to bring together the range of specialized researchers and designers that is required to meet these challenges, and to advocate for appropriate solutions. Since then progress has been made in identifying and analyzing risks, finding potential solutions, and in gathering support for the implementation of hazard reduction strategies. These studies and the proposals that followed address the specific and unique characteristics of the upper Texas Gulf Coast and the Houston-Galveston region, but they also suggest a model for responding to the global forces of climate change, sea level rise, and continuing urban and industrial growth. They demonstrate that design can meaningfully engage these issues and participate in the development of public policy.

Ongoing research into the dynamics of severe weather events has provided a detailed picture of the risks to homes, businesses, constructed and

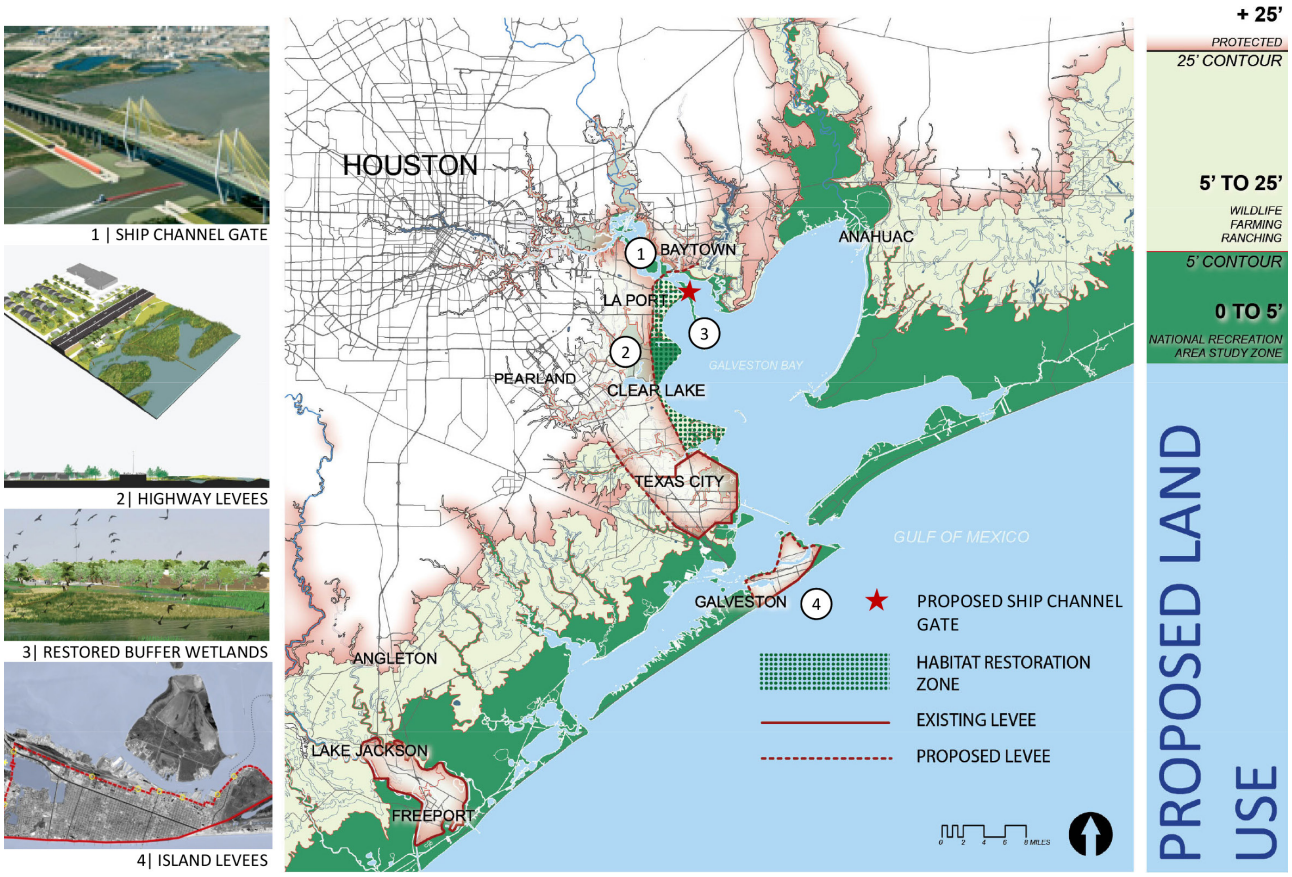

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Figure 1: Layers of protection. Nonstructural solutions include a National Recreation Area that would dissipate storm surge while providing economic and recreational opportunities.

natural infrastructure, and industries throughout the region. Related floodplain and storm surge maps, land use, ecological, and related studies have outlined the requirements to be met in protecting the Houston-Galveston region. They have also formed the basis for the development of a regional plan that includes four basic coastal protection and enhancement proposals including structural and non-structural components. A suite of alternative levee alignments, gate structures and associated urban and environmental improvements have been proposed to protect and benefit the economic heart of Galveston Island, communities along the western shore of Galveston Bay and the Clear Lake area and, of critical importance, the Port of Houston and industries located along the Houston Ship Channel. Non-structural protection proposals include the proposed million-acre Lone Star Coastal National Recreation Area to be located along the Texas coastline from Matagorda Bay to High-Island.

THE PORT OF HOUSTON

The Houston Ship Channel and the Port of Houston were developed as a direct result of the destruction of the City of Galveston in 1900. Seven to ten thousand people died in that storm. The true number of casualties will never be known, but it was immediately clear that a safer harbor was needed to bring agricultural products to national and international markets and immigrant labor and industrial products to Texas. The discovery of oil and subsequent development of the oil industry brought enormous growth to the region. Refineries, chemical processing plants, and the construction of vast pipeline networks linking them all together ultimately lead to the

Port of Houston becoming the nations number one port for international trade. Today the Port of Houston includes over twenty thousand acres of heavy industrial development, not including adjacent more inland refineries and storage facilities. The Port generates 178.5 billion dollars in economic impact to Texas each year, generating 4.5 billion dollars in tax revenues. It accounts for over a million jobs in Texas alone. Much of the Port of Houston lies at or near sea level, close to the center of the City of Houston.

For many years experts have warned that the Port is vulnerable to hurricane related tidal surge but there was little agreement that this could possibly be the case. After all, the Port is located fifty miles from the Gulf of Mexico and well behind the state's barrier islands. But the devastation caused by Katrina and later by Ike gave rise to important new SSPEED funded scientific studies examining the possibility of storm surge impacts and in depth examination of the vulnerabilities of the Ship Channel. Leading the analysis of surge risks, the Computational Hydraulics Group at the University of Texas, long Texas' primary resource for surge analysis and forecasting, has been able to show what would occur if an historic storm had hit at a different location or if it had been more severe. Their analysis has shown that if Hurricane Ike, a Category II storm had landed to the west of its actual landfall, the flooding in the Houston Ship Channel would have been devastating. If Ike had been a bigger storm hitting at this location, the results could have resulted in approximately twenty-five feet of tidal surge throughout the Ship Channel. Using those projected surge levels other researchers have undertaken a precise analysis of the Ship Channel area, locating industrial facilities in relation to floodwater. It was found that in an event such as this over 1,700 major chemical storage tanks would be inundated and many thousands of acres of pumping, processing and shipping facilities would be put out of commission. Among the many facilities that would be hard hit, the Baytown Exxon Refinery alone can process over 565 million barrels of oil per day and produces, among many other products, a large portion of the nation's aviation fuel. Obviously, the consequences of a severe storm coming ashore anywhere near the west end of Galveston Island could include devastating toxic releases on a massive scale. Such an event would have major impact on local, state and, national economies.

Detailed analysis of local topographic conditions and surge tide models has revealed a possible solution. Land on either side of the mouth of the Ship Channel as it opens into Galveston Bay is high enough to protect against the intrusion of tidal surge if these ridges are connected across the mouth of the Ship Channel by a short levee and a surge gate to allow passage of ocean going vessels. Initial design studies for the gate have concentrated on two concepts: a larger scale version of the "double arc" design employed in the Netherlands, and a floating caisson concept. Both of these concepts are now undergoing engineering and urban impact analysis and design studies. The dual objectives of this effort are to protect the port while at the same time finding opportunities to improve surrounding districts. One way to accomplish all this is to design the levee connecting the channel gate structure to the mainland on either side to provide public access to channel islands that now serve as dumping grounds for channel dredging spoils and as constructed wetlands and nature preserve. These islands could maintain their current uses and also accommodate ecotourism and other forms

of recreation in an otherwise barren industrial district. These design concepts are being developed even as the concept of the gate is being tested by ADCIRC and rainwater flood modeling for hydrological effects on surrounding areas. In focus groups, local citizens have been rightly concerned to know, "If this is built, where will flood waters go and how can these areas be protected?"

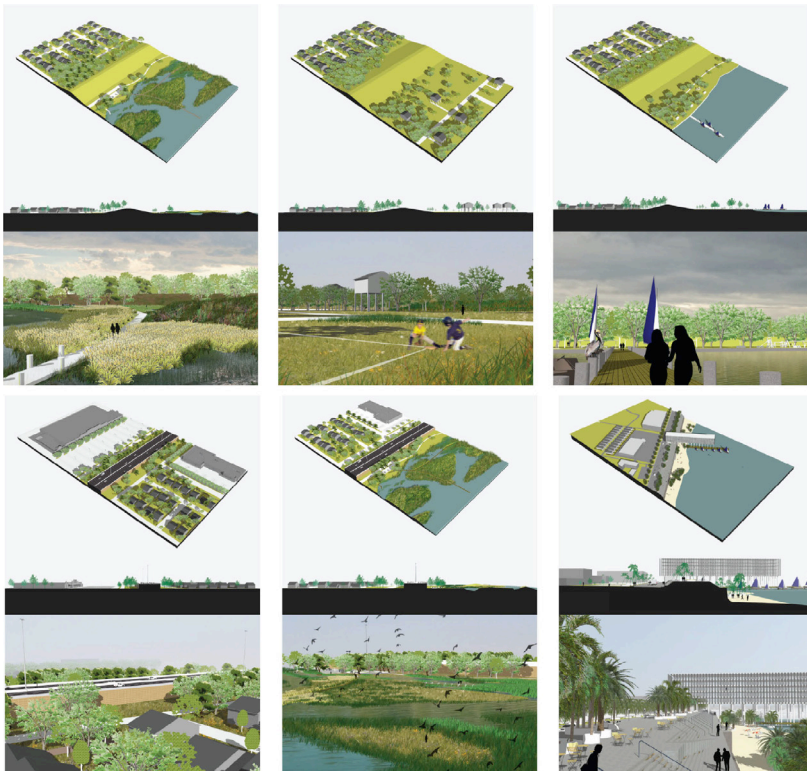
THE WEST SHORE OF GALVESTON BAY

Directly to the south of the Port of Houston lies the West Shore of Galveston Bay Including the Clear Lake – Kemah area. Storm modeling demonstrates that the area is also susceptible to up to twenty-five feet of storm surge with up to six-foot waves on top. The questions that arise from this stark fact are: what is at risk and how can this area be protected? GIS analysis reveals almost a quarter of a million people living within the one hundred thousand acre tidal surge area of this rapidly growing region, as of the 2010 census. A population of a half million is anticipated in the near future. Almost eighty two thousand jobs are located here. Privately held land in this region is appraised at twenty billion dollars in value. The headquarters of NASA, The University of Houston Clear Lake, forty-three schools, twelve fire stations, two hospitals, and fifty-four sewage outfalls are all at risk.

While this heavily developed and rapidly growing area would clearly benefit from the construction of a coastal levee system it must be said that other alternatives exist. Hardening infrastructure and raising minimum floor levels to an adequate height or local private levees could protect many people and institutions. NASA for instance has abundant land on their campus, and much of the campus is located over twelve feet feet above sea level. For NASA it would be a simple matter to move enough earth within its campus to protect all of its facilities. For smaller sites and sites that are closer to sea level this is not an option. However, the possibility of site-limited protection is likely a contributing factor in the rejection of protective levee systems by community representatives in local focus groups. Another factor in the resistance to structural protection is the staunchly conservative culture of the region leading to calls for the rejection of all forms of "nanny government" including levees.

Despite the existence of other alternatives and resistance from some individuals, for most people a levee is necessary. A levee along the waterfront could protect everyone. This would be a good solution in part because a levee in this location would be simple to construct using barges to economically transport materials, and because expensive right of way would not have to be purchased. But, Galveston Bay ecosystems would be impacted and waterfront property owners can be expected to object to loss of view and privacy. Given the likelihood of strenuous objections by coastal homeowners, it is fortunate that another practical levee alignment exists.

Sate Highway 146 parallels the coast and its right of way is wide enough to contain an elevated highway/evacuation route and levee. According to LIDAR surveys, and engineering records, much of the highway is already high enough, or nearly high enough to serve as a levee. If SH 146 were to be redeveloped as a protective barrier and secure evacuation route, the vast majority of the region would be protected although residential districts that are outside the levee would remain unprotected. Over time, as areas outside



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the levee are battered by storms and rising sea levels, people will begin to move away. As fewer and fewer residents live there, utilities and other infrastructure are likely to become too expensive to maintain. This means that the area is likely to be abandoned and gradually return to its native wetland state. In the meantime, with hardened infrastructure homes and larger buildings can be built if they are elevated above surge height and if wave action is minimal. Wave action and debris are what cause the most destruction during storm events. While wetlands and oyster beds cannot slow tidal surge, they can break up wave action. Oyster beds can be constructed just off shore to break up waves and allow transitional building development. Wetlands will naturally occur throughout the area and at the water's edge. These factors could facilitate continuous occupation of the area until it is overtaken by rising sea levels.

Occupation of this transitional zone outside the levee system will present unique challenges and opportunities for creative ecological, urban, and building designers. For environmentalists, the return of this area to a wetland state would be an ideal result. Some of the thousands of acres of wetland that used to border Galveston Bay would be restored, improving biodiversity, the bay's fertility, and water quality. The question is, how can such an area be occupied in an environmentally appropriate and resilient manner. Promising design projects are being developed to examine these challenges.

Wherever a levee is built issues of urban integration and environmental quality need to be addressed. Adjacent urban or natural conditions can be seriously impacted. Beneficial multi-functional structural protections can engage adjacent land uses including park systems, restored wetlands, waterways, neighborhoods, and commercial districts. Achieving the right mix of urban amenity, natural systems restoration, and functional design is

Figure 2: Multi-Functional Infrastructure. Neighborhoods enhanced and protected. Unprotected areas developed to withstand storm forces or for ecosystem benefits.

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a challenge that is being addressed through the development of a menu of coastal, district and neighborhood design studies.

GALVESTON ISLAND

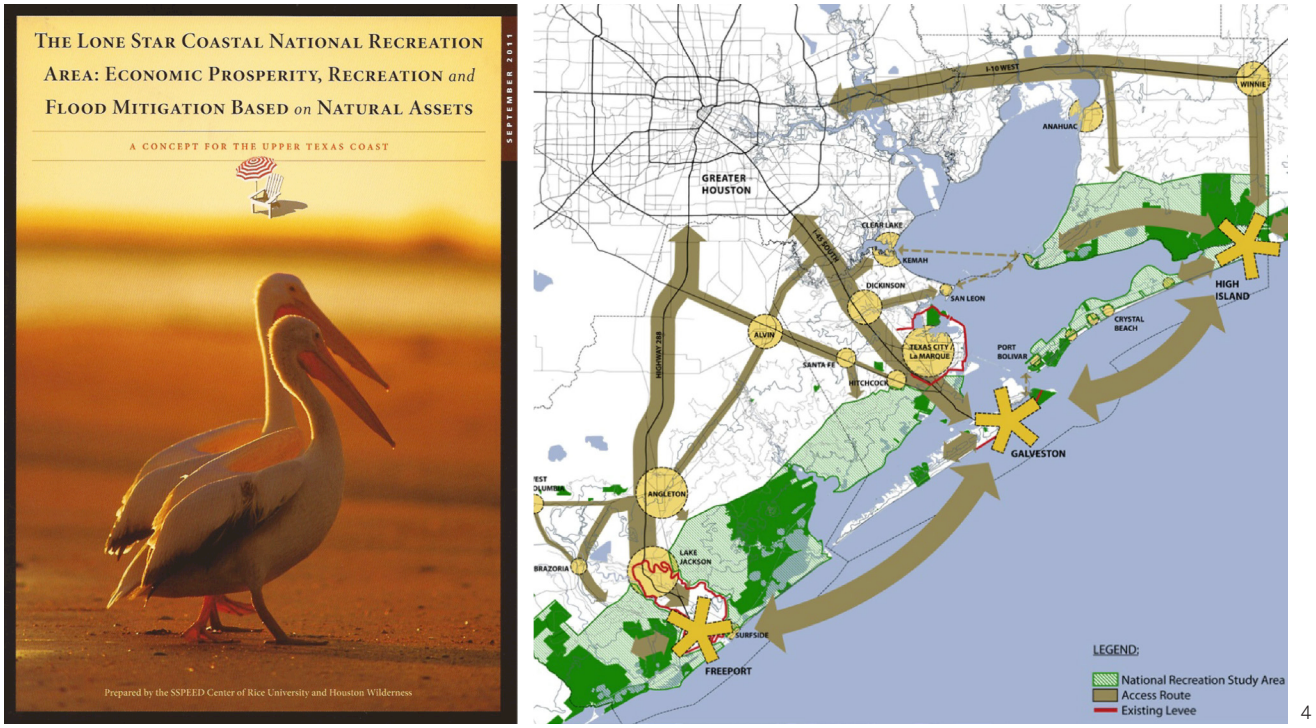
Following the 1900 hurricane, a seventeen foot sea wall was built along the ocean side of the densely developed east end of Galveston Island. Huge amounts of sand were then pumped onto the island to raise ground level to equal the height of the sea wall. Buildings throughout the affected area were raised while this earth moving was under way and then lowered onto the new grade. The original plan was to raise the entire island to seventeen feet above sea level but that proved too expensive. Instead the island now slopes down toward the Galveston Bay side where its waterfront elevation is a mere four to five feet above sea level. This leaves the area behind the sea wall susceptible to flooding from the bay, which is exactly what happened in Hurricane Ike. To protect against this happening again it is proposed to extend the sea wall around the north side of the island. In an already densely developed and historically significant area, this becomes a complex and politically challenging urban design issue. Various alignments have been studied and presented at stakeholder meetings to achieve public support. But besides completing the enclosure of the east end of the island another challenge faces the east end of Galveston.

Analysis of meteorological history has revealed one percent probability in any given year of tidal surge in excess of twenty above sea level. This is approximately the height of coastal surge to the east of Galveston Island that occurred during Hurricane Ike. Anticipated sea level rise of three to five feet reinforces the fact that the existing sea wall is too low. In today's political and economic climate it would not be possible to further raise the island and all the structures on it. This means that in order to protect already developed areas the sea wall must be raised in a way that puts Galveston's spectacular shop-front ocean views and the feeling of urban connection to the beach at risk. The public and local businesses must be given access and they must feel connected to the waterfront. Ongoing design studies are intended to explore new relationships to the waterfront and present a menu of possible solutions to this problem.

THE LONE STAR COASTAL NATIONAL RECREATION AREA

If structural protections at the mouth of the Ship Channel, along the west shore of Galveston Bay, and in Galveston are built the Houston-Galveston regions most densely developed districts and most valuable industrial and

Figure 3 : Galveston Island. Re-establish lost wetland buffer and complete structural enclosure.



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commercial sites will be safe. But urban development continues in other areas including many areas along the coast that are only a few feet above sea level. Much of this land is pristine salt water, brackish and fresh water marsh. The allure of waterfront development seems to blind real estate developers to the moral hazard they are creating. Homeowners are frequently often completely unaware of the serious dangers they face in living in these low-lying areas. The proposed Lone Star Coastal National Recreation area is intended to address this issue while at the same time protecting vital ecosystems and creating economic and recreational opportunities for the upper Texas Gulf Coast.

The LSCNRA proposal calls for much of the undeveloped coastal land that is located below five feet above sea level to join a voluntary partnership for land management. This partnership would support synergistic opportunities for economic development while limiting real estate development. Modeled on creative network governance structures and projects such as Boston Harbor Islands National Recreation Area, private, public, and NGO members would join the organization to obtain assurance with respect to what would or would not be built next door and to obtain other economic benefits of the overall agreement. This partnership would reside under the umbrella of the National Park Service and will require an act of Congress to be implemented.

Since much of the land in this region is already controlled by government agencies, NGO's and large-scale private landowners, not as many participants would be required to substantially affect future coastal development patterns as might be imagined. But no matter how many participants in the LSCNRA each would enter under individually negotiated contractual agreements representing their unique interests within the overall framework of the organization. Large agricultural landowners might agree that their land

Figure 4 : Lone Star Coastal National Recreation Area, Economic Gateways.

is to remain in agricultural use or it might be allowed to revert back to wilderness. They could enjoy the economic benefits of carbon sequestration, and mineral extraction but their land would be protected from future real estate development. Fishing industries and coastal communities might agree to continue with those uses but agree to not allow major industrial development in future. Especially sensitive nesting grounds might be protected from any public use. Some areas might be set aside for hunting, sport fishing, or boating. In general, recreational and eco-tourist activities, and the benefits of ecosystem services would be encouraged. Management and marketing of these opportunities would be coordinated under the umbrella of the National Park Service.

A study by the Harbinger Consulting Group projects that the LSCNRA will attract a half million visitors in its first year eventually rising to one and a half million visitors per year. This will result in one hundred and ninety million dollars in local sales per year. Among the other ecosystems benefits of this proposal, the area would continue to act as a sponge to absorb and slow floodwaters and to dampen wave action in major storms. One of the world's great migratory bird routes would remain in tact, and while the wetlands of South Louisiana are fast disappearing, these wetland areas would remain as a vital ecological reserve to ensure the continuing fertility of the Gulf of Mexico. For architects, this proposal creates the extraordinary challenge of building in risk prone sites in a way that will allow maximum appropriate access to sensitive waterfront and wilderness lands.

CONCLUSION

These proposals call for restructuring the upper Texas Gulf Coast as a layered defense system that incorporates structural and nonstructural components. They are based on detailed analysis of specific localized risks and are designed to accommodate the universal challenges of sea level rise, ever more frequent and intense storm activity, and continuing urban development. They include planning and design strategies that will benefit local communities by providing economic, recreational, and ecosystem services benefits. As integral parts of these recommendations, coastal wilderness areas will be restored and protected. Recreational and cultural opportunities will be coordinated and enhanced. Densely developed settlements and industrial areas will be protected, and those protections will be sewn into adjacent landscape and neighborhoods in ways that will create enhanced urban environments and expanded recreational opportunities. These proposals, if implemented, will fundamentally alter future development patterns along the upper Texas Gulf Coast. Implementation is by no means guaranteed but it must be mentioned that as of this time these proposals are gaining support at every level of government and in the business community. This has been possible in large part because of the integration of scientific validation into the design process and because design proposals have been able to make science tangible.

While this effort follows the well-trodden path of speculative design and planning projects engaging real world problems and seeking implementation, it is of interest in relation to architectural education in several respects. First, it situates design in a unique multi-disciplinary context in which design not only follows but also drives applied scientific research and the

development of fundamental public policy proposals. Second, it carves out a design role that challenges disciplinary silos that have for many years separated architecture from planning, urban design, and landscape architecture. In this context it is impossible to separate these activities. The breadth and complexity of issues involved suggests that if schools of architecture wish to engage the challenges of climate change and regional design, courses and studios will have to be developed to operationalize working relationships with disciplines that have until now had little or nothing to do with design education. Studios will need to challenge traditional disciplinary boundaries. Discussion of the ways that large scale projects can be developed to effect public policy decisions will need to be incorporated in studio teaching. Studio projects will need address issues outside their normal comfort zone.