# STRATEGIES AND GOALS

# 11. Overview of Management Strategies for a Better Dickinson Bayou Watershed

The stakeholders of the Dickinson Bayou watershed want to see a “better” watershed in their future. That “better” state is not a precisely quantifiable end point but it obviously means no further degradation. Stakeholders are clearly concerned about the impact of new development, particularly if it is “sprawl-like.” They would like to see new development shaped by codes and ordinances that protect and enhance natural resources. **Citizens of the watershed recognize that Dickinson Bayou water quality is not what it should be** and they would like to see less stormwater runoff with much higher water quality.

The State would ultimately like to see a more precise end point, that of meeting regulatory stands of the Clean Water Act. Bacteria levels are much higher than they should be, and dissolved oxygen is consistently lower than it should be. Because of the peculiar bottom contours and flow characteristics of the Bayou, meeting the DO standard is particularly difficult, and by some accounts may not be possible at all given the characteristics of the Bayou. The State is struggling to determine just how close, given both biophysical and financial constraints, the water quality in Dickinson Bayou can get to the current state standards.

This watershed plan is an attempt to map out a strategy for achieving both the broad goals of the citizen stakeholders as well as a closer approximation to the current State water quality standards for the Bayou. The following sections outline specific strategies and practices that can be put in place to help achieve these goals. Where appropriate, expected reductions in pollutant loading are detailed for each practice, as well as the cost of the practice and some suggested milestones for implementing the practices. We separated the goals and potential load reductions into short (~5 years) and long term (10-20 years) time frames. Rather than setting intermediate goals, it is recommended that these goals be revisited at least every 5 years and be reevaluated based on experience and changing conditions.

We have selected strategies that we know will make significant impacts in load reductions, or that in some cases at least minimize increases in loading (e.g., land preservation and liveable centers). We do not, however, have enough data to precisely quantify sources for every pollutant, nor can we precisely quantify exactly how much reduction we can expect from any given practice. We have taken the load reduction values from published studies, and while these are extensive, there is considerable variation in the expected efficiencies for any one practice.  It should be remembered that these are estimates but, qualitative estimates should not be dismissed as less than useful. These estimates do give us a very good sense of the magnitude of the task ahead as well as where we can get the best result for the money.

This plan focuses on reductions in total nitrogen, total phosphorous, and bacteria. The recently completed draft TMDL reports for dissolved oxygen for both the tidal and non tidal portions of the Bayou targets a 10-11% reduction in CBOD[46] loading from all sources. We do not directly target reductions in CBOD as part of this plan, because we have no way of directly estimating how effective the selected practices are in reducing this pollutant[47]. Given that CBOD appears for the most part to be associated with wastewater in one form or another, we are assuming that the practices this plan recommends for bacteria reduction will address CBOD as well.

The short term (~5 years) target for Total N and Total P is a reduction of 23,394 lbs/yr and 5,816 lbs/yr (5% and 6%), respectively. The long term goal is 267,968 lbs/yr for Total N and 86,634 for Total P. For bacteria, the short term goal is a reduction of $1.9 \times 10^6$ billion colonies/yr (15%) our goal will be sufficient reduction to achieve the state standards.[48] The long term goal is a reduction of 267,968 lbs/yr for Total N (32%), 86,624 lbs/yr for Total P (23%) and $1.6 \times 10^7$ billion colonies/yr for bacteria (46%).[49]

**Short Term Loading Reductions**
- 5% Total Nitrogen
- 6% Total Phosphorus
- 15% Bacteria

**Long Term Loading Reductions**
- 32% Total Nitrogen
- 23% Total Phosphorus
- 46% Bacteria

We begin by looking at ways to maintain our organizational structure and cohesion as a watershed partnership – a key to maintaining momentum and progress. The next section details an overall educational strategy to raise awareness of watershed issues amongst the general populace of the watershed. We then review options for preserving natural areas and enhancing the ecological services (e.g., clean water) that these areas provide us.

We evaluate options for improving wastewater discharges, from both permitted sewage systems and from potentially failing septic systems, perhaps the major contributor to low DO levels in the Bayou. There are no easy or cheap solutions for improvement in this area, particularly for septic systems.

The next few sections review practices that reduce stormwater runoff and pollutant loadings at the site level, from landscapes to pervious pavements to green roofs and more. Stormwater treatment wetlands are a larger scale approach that looks to be one of the most efficient ways to improve stormwater runoff water quality in our area, and we deal with this in a separate section.

Finally, we look at how building “livable centers” can provide some of the best opportunities for achieving pollutant load reductions while addressing some of the quality of life issues that concern so many of the citizens of the watershed.

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[46] Carbonaceous Biological Oxygen Demand
[47] The National Pollutant Removal Database Version 3 (2007) by the Center for Watershed Protection, for example, does not list CBOD amongst of the pollutants analyzed for best management practices.
[48] See Section 23 for calculations.
[49] Long term percent reductions are based on projections for 2009 with the full build out of the watershed at medium density, see Section 23 for full calculations

The strategies in this *watershed* plan look at the watershed as a whole, and recommend those management options that impact the most areas and provide the most improvement in water quality with the least expenditure of money. For example, stormwater treatment wetlands provide water quality treatment, habitat and add beauty to our environment.

# 12. Strategies for Organizational Continuity

## *A Permanent Watershed Coordinator*

Of the top ten watershed lessons learned by the U.S. Environmental Protection Agency[50] (1997), the presence of a permanent watershed coordinator is ranked number 3. The many and differing entities operating in the watershed all have their own particular mandates and agendas. None of them has a specific mandate to collaborate (although it could be argued that there is an implicit public mandate for collaboration since the public does not expect agencies to work at cross purposes and the public also assumes agencies will work more efficiently without duplicating efforts). A watershed coordinator was in place for more than two years in the Dickinson Bayou watershed, funded through grants from the Galveston Bay Estuary Program. Without that coordinator, the watershed partnership would not have been formed, committees would not have been organized, and strategies and goals would not have been set. Given the present state of the partnership, at least a half-time watershed coordinator would be required to keep the momentum going that has been established so far. A full-time coordinator will be required to take the partnership to the next level.

A full-time watershed coordinator could serve the partnership municipalities in meeting their Phase II TPDES stormwater requirements, particularly in terms of education and outreach, as well as implementation. Any investment in a watershed coordinator position would thus have immediate benefits.

It is unreasonable to expect any one particular agency or entity to shoulder the full burden of the salary for a watershed coordinator. A pro-rata share based on population could be determined to spread the cost more evenly across the watershed.

## *Permanent Organization*

The Dickinson Bayou Watershed Partnership has a fairly well defined organization, but has no formal structure or permanence. The Watershed Partnership needs to be an independent organization if it is to have any power or permanence. There are a number of organizational structures that could be explored. An independent 501(c)3 organization is one possibility, with a financial commitment from the member entities. A formal organizational structure does not mean the Partnership would have any regulatory power. It would simply mean that a formal structure exists for cooperation at the watershed scale.

## *Strategy*

- Hire a permanent watershed coordinator
- Set up an independent entity for the Dickinson Bayou Watershed Partnership

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[50] USEPA. 1997. Top ten watershed lessons learned. EPA 840-F-97-001. National Center for Environmental Publications. Washington, D.C.

## ***Financial requirements***

- Watershed coordinator:  $70,000-$100,000/year, inclusive of salary, benefits, and limited operating costs.
- Operating Costs 501(c)3:  Perhaps $20,000/yr in addition to coordinator requirements listed above

## ***Milestones***

- Seek grant funding for coordinator: 2009
- Solicit member funding: 2009
- Hire coordinator: 2009
- Establish 501(c)3: 2010

# 13. Strategies for Publication Participation and Education

Education and outreach will be key components to the success of this watershed protection plan. Reaching out to citizens and municipal officials, showing them how to help, is essential. It will take a coordinated effort of many entities to make this happen. A full time watershed coordinator is essential to creating and maintaining watershed-wide education efforts. Also, many of the education programs suggested below will meet at least a portion of TPDES permit requirements for cities in the watershed. Incorporating permit needs will be an important way to help fund these programs. Cities will need to designate funds for stormwater education programs. Combining at least a portion of these resources will stretch limited funds and benefit everyone.

## *Strategies*

**Present a common unified message.** The most important piece of the education puzzle is unity. A unified message must be presented across cities and throughout the watershed. This is especially important in terms of ordinances and implementation practices. One city should not undo the good work of another.

**Targeted Outreach Campaign.** A large scale campaign similar to Houston's *Clean Water Clear Choice* program should be developed for the watershed. This will require the cooperation of many organizations and a significant amount of funding. It should use all types of media available: television, radio, newspaper, magazines, signs, posters, brochures, handouts and the internet. All in an effort to reach every person in the watershed with the targeted message discussed above.

**Brand Recognition for Dickinson Bayou Watershed.** A logo has been developed for the Dickinson Bayou Watershed Partnership and this group needs to be marketed so it is a house-hold name. Every person in the watershed should be familiar with the partnership and its mission.

**Strategy Implementation Workshops.** Most of the strategies for implementing the watershed plan will require a workshop component for education. The key is to target workshops to the most appropriate audience: homeowners, developers, public officials, etc.

**Publications** are still one of the best ways to reach a large audience. A well-designed, informative brochure, fact sheet or hand book can be pulled out for reference time and time again. These can be handed out at events and workshops or placed on display at local businesses and libraries. These can also be made available online to save on printing costs.

**Programs for school children** in the classroom and through extracurricular programs (Boy or Girl Scouts, science clubs, 4-H, etc) are a fun way to reach the youth of the watershed. Many simple, inexpensive and interesting activities exist for all age groups. Packaging these in a way that teachers or volunteers can easily understand and present to groups and linking the relevance to our watershed are the keys to making these programs successful.

## *Targeted Goals and Actions*

1. Establish a brand (logo) and develop a marketing plan for education and outreach for the watershed to include:
   - Signs- watershed entry signs, bacteria warning signs, information signs, etc.
   - Social Activities – to include attending conferences, providing town hall meetings, helping with Trash Bash, attending social events such as community fairs and festivals, etc.
   - Brochures – create 2-fold brochures for the adult population and a 3-fold brochure for youth and children.  Create various posters and flyers.
   - Demonstrations – Create WaterSmart Landscaping BMP demonstration sites
   - Surveys & Polls – develop several surveys and polls within the context of a community planning and town hall meeting as well as the Watershed Partnership
   - Press releases and Public Service Announcements – Develop quarterly press releases of Watershed Partnership activities and goals achieved

2. Develop key themes to serve as core messages to be incorporated in promotional materials and classroom/workshop activities by jurisdictions and organizations in the watershed.

3. Develop partnerships with Education and Outreach organizations to engage the general public and share resources for common goals in volunteer water quality monitoring for the Dickinson Bayou watershed to include:
   - Texas Stream Team volunteer water quality monitoring
   - WaterSmart Landscaping
   - Keep Dickinson Beautiful
   - Service Clubs
   - Youth Groups and Scouts
   - Non-Government Organizations

4. Recruit  influential spokespersons and friends of the Partnership to include:
   - Elected officials such as county judges and commissioners, city mayors and council members, state legislators or congressional representatives
   - Irrigation District Managers
   - Drainage District Managers
   - Media Personnel
   - Chamber of Commerce
   - Civic Organizations
   - Clergymen or women with a high community profile
   - Business or community leaders with a high profile in community affairs

5. Promote Stormwater Best Management Practices (BMPs) within the watershed.

6. Encourage municipalities within the watershed to actively participate as stewards of the watershed by:
    - Attending Meetings – Watershed Partnership representatives/members should attend City Council, Chamber, and civic group meetings
    - Reviewing rules, laws, and ordinances relating to the watershed – complete the “gap” analysis of various rules, laws, and ordinances as they relate to stewardship and management of the watershed
    - Promoting the Dickinson Bayou Watershed Protection Plan

### *Financial requirements*

A big push is needed during the first several years to really begin implementation of this watershed plan. A proper multimedia campaign is key to kick starting this effort and will not be cheap. An investment of $2.5 million over the first five years would likely fund this effort and create the educational tools needed. A smaller investment, around $100,000, each year after that will keep programs operating and allow for expansion and growth.

However, impacts can be made for a smaller investment. Creating partnerships, developing key themes, writing press releases, recruiting influential spokespersons and encouraging municipalities to become watershed stewards are all FREE. Signs for BMP demonstration sites can be designed and installed for $1,500 each, watershed and BMP specific factsheets and brochures can all be produced for around $1,000 each, or less if they are not printed but made available solely on the internet.

### *Milestones*

- Development of 3 key themes community partnerships– 2009
- Five watershed workshops held, and 10% of households/businesses reached – Fall 2010
- Four outreach events attended by a Watershed Partnership Representative– 2010
- Ten watershed specific publications produced - Fall 2014
- Twelve demonstration sites (WaterSmart Landscapes, rain gardens, construction site BMPs, LID BMPs) –2010
- Implementation of outreach campaign –2014

# 14. Habitat Strategies

## *Conservation*

Natural areas provide huge benefits in terms of water quality and flood prevention (Figure 17). But we only reap these benefits if the land is in its natural state. While good habitat remains in the Dickinson Bayou watershed, it will all be gone in just a few years if present trends continue. **Conservation of high quality natural areas** is one of the most important things we can do to help maintain and improve the water quality in Dickinson Bayou.

In the best of circumstances, *all* high or medium quality habitats remaining in the watershed should be preserved, given the scarcity of virtually all of the remaining habitat types in the watershed. This would translate to over 13,000 acres and a price tag close to $1 billion! This aspiration, while noteworthy, is largely unattainable. Perhaps a more realistic preservation goal of 30% of the remaining habitat or 4,200 acres would be justifiable and attainable (Table 11). At current market prices, conserving 4,200 acres of land in the watershed would still cost $300 million—not a cheap price!

***Table 11: Number of acres by habitat type targeted for protection within the Dickinson Bayou watershed***

| **Habitat Type** | **Acres Remaining** | **Targeted acres for Preservation** |
|---|---|---|
| Estuarine | 46 | 46* |
| Prairie Pothole 1 (prime condition) | 5,118 | 1,536 |
| Prairie Pothole 2 (moderate condition) | 8,156 | 2,447 |
| Prairie Pothole 3 (somewhat degraded condition) | 5,105 | --- |
| Riparian Forest | 838 | 252 |
| **Total** | **19,263** | **4,281** |

* All estuarine land is considered preserved because current State of Texas permit requirements aim to protect these areas and make developing them difficult.

If habitat is to be preserved, it must be preserved in large-enough blocks to have some ecological significance. One hundred acres is considered a minimal amount of land for a single preservation parcel, with greater value gained as larger pieces are interconnected through corridors of one type or another.[51] A good example of land preservation, albeit mitigation through preservation, is the League City Prairie Park on Highway 96 near the intersection of Highway 146 and the Mar Bella subdivision. The City of League City purchased 44 acres of prime condition land and is preserving and managing this land as a nature park open for public use. This allows for education about and understanding of natural areas while preserving quality habitat for animals and the additional benefits of these areas. Mitigation, therefore, where appropriate and permitted may be a means of preserving prime habitat.

There are also ways to preserve land without purchasing it. *Conservation easements* allow the owner to maintain the property and makes them promise to keep the land in a natural state in perpetuity. These easements restrict development, commercial uses, industrial uses, and certain other activities on a property. Easements are agreements between the property owner and a government agency or land trust.

**$300 Million for Land**
**vs.**
**$300 Million for a Sports Stadium**

The benefits of natural lands are not always easy to see because they have been there all of our lives. We don't realize these benefits until they are gone. Preserving natural land in the Dickinson Bayou watershed will likely cost around $300 million. *This is a lot of money.* But we must ask ourselves, how much is our history worth? How much are we willing to pay for our great grandchildren to reap the same benefits from the land that we do?

Minute Maid Park, home to the Houston Astros, cost $250 million to build. Reliant Stadium, home to the Houston Texans, cost $352 million to build. In 100 years what will be left of these stadiums? Crumbing piles of concrete and steel? Memories? Photographs?

In 100 years what will we see on natural lands? If they are protected, the same ecological and flood mitigation benefits we see today and have seen for tens of thousands of years. *They will still be a place to take our families and remember our heritage*. It will be the same untouched land of our ancestors.

*What is the best use of **your** money? Continues benefits or temporary benefits that leave behind piles of rubble?*

The Clean Water Act (CWA), Section 404, is the only federal law that protects a specific land category, namely wetlands. While municipalities do not have jurisdiction over wetlands under current federal and state law, they can require developers to comply with the federal statutes before granting any building permit within their jurisdiction. Simply requiring evidence of Section 404 compliance will yield more mitigation than is currently provided. Mitigation can include

[51] Environmental Law Institute. 2003. Conservation thresholds for planners. Washington, D.C.

preservation and enhancement of existing wetlands. Insisting that this mitigation occur within the watershed could be a very significant way that important pieces of habitat get preserved at little or no cost to the municipality.

### *Restoration*

Native lands in moderate condition offer many of the same benefits as land in prime condition. However, restoration efforts can rehabilitate this land back to a prime condition and *all* of its natural benefits. Many conservation agencies and organizations in the area are interested in habitat restoration projects but funding and labor is required to make them happen. Many grant programs exist to fund restoration projects and volunteers from master naturalists to Boy Scouts, can help with labor.

### *Habitat Management Plan*

The development of a watershed-wide habitat management plan will be a collaborative effort between several agencies, counties, and cities. The watershed coordinator could help facilitate this process, by bringing groups together with knowledgeable professionals, helping to write portions of the plan, and working to make sure the goals of all groups and the watershed as a whole are met through this process.

An important component of a Habitat Management Plan is invasive species management. This ongoing issue if left unchecked often leads to degradation of native habitats. It is especially important to include non-chemical methods of control as these chemicals are adding to the poor water quality in Dickinson Bayou.

### *Education*

Workshops should be held for land owners about conservation easements and the basics of entering into such an agreement. These short workshops should also include basic habitat information, ecological services information and examples of successful conservation easements.

### *Expected Pollutant Load Reduction*

There is no load reduction set for the present time. Load reduction will be seen over time by not developing natural areas.

If the short term goal of preserving 1,000 acres is met. We will NOT see an additional 20,252 lbs/yr (4.3%) of total nitrogen, 4,797 lbs/yr (4.6%) of total phosphorus, and $6.2 \times 10^5$ billion colonies (4.7%) per year poured into Dickinson Bayou.[52] If the long term goal of preserving 4,200 is met, we will NOT see an additional 85,059 lbs/yr (18.1%) of total nitrogen, 20,147 lbs/yr (19.4%) of total phosphorous and $2.6 \times 10^6$ billion colonies/yr (19.7%) of bacteria enter the Bayou each year. [33] Thus, preserving this land will decrease the annual load by these amounts.

[52] Complete calculations in Section 23

## *Targeted Goals and Actions*

- Identify valuable natural habitats and develop a plan to preserve and/or restore these areas
- Identify wetland areas for restoration and develop a restoration plan
- Develop a mitigation plan to identify the most effective use of mitigation dollars to preserve habitat within the Dickinson Bayou watershed
- Estimate, in detail, the amount of remaining forested riparian habitat within the watershed
- Develop a habitat conservation management plan specific to each piece of preserved land
- Work with landowners to preserve land through conservation easements
- All municipalities within the watershed require full compliance with CWA Section 404 before granting any building permits, and insist that any mitigation be accomplished within the watershed.

### *Financial requirements*

Purchasing land is not cheap, but must be done to protect our watershed and our bayous. At current market prices it will cost $300 million to purchase land. These costs could be shared by many groups, including cities, and counties, not-for-profit organizations, and private donors. Grants can be leveraged to purchase property, as well as bond issues or tax revenue; if cities choose to implement a stormwater fee, a portion of these funds could also be used. It will require a concerted effort of the Partnership for land preservation to be effective. CWA permitting and mitigation could yield land, easements and/or restoration opportunities in the watershed.

Minimal funding of $180,000 over several years would also be needed for additional projects. Fifty thousand dollars is needed for workshops on preserving private land with conservation easements and a homeowners program. A watershed wide mitigation plan would require funding of $30,000 and a habitat conservation plan would require funding of $100,000. This work and much of this cost could fall under the duties and funding of a watershed coordinator.

## *Milestones*

- Hold 2 public workshops on preserving land though conservation easements: 2014
- Develop a watershed wide mitigation plan: 2014
- Develop a watershed wide habitat conservation plan: 2014
- Preserve 1,000 acres of habitat in the watershed: 2014
- Preserve 2,500 acres of habitat in the watershed: 2019
- Preserve 4,200 acres of habitat in the watershed: 2029

# 15. On-Site Wastewater Strategies

## *Establish a clear linkage between failing on-site sewage facilities (OSSFs) and water quality*

A presumptive link has been identified between failing OSSFs and high levels of CBOD and bacteria in Dickinson Bayou. Given that remediation of failing OSSFs is an expensive project, a detailed investigation of the actual contribution of OSSFs to the water quality problem seems mandatory. Such a study would require multiple sampling events near areas with concentrations of OSSFs, sampling overland flow during periods of rainfall, and sampling tributaries after rainfall events as well as base-flow measurements.

## *OSSF enforcement and maintenance*

Since 1997, state regulations require that OSSFs be designed to accommodate limiting factors in the soil and on the site. There are serious soil limitations for OSSFs in the Dickinson Bayou watershed, mainly shallow water tables and very clayey soils (see Figure 5). Standard soil leach-field systems do not treat and dispose of domestic wastewater to current standards. Advanced treatment and disposal systems are required for problematic soils. Table 8 shows considerable progress in the installation of advanced systems over the past decades, but as of 2006, 23% of all systems permitted in Galveston County were still standard leach-field systems. Flat-lying and adjacent Harris County, likely somewhat better drained than Galveston County on average, permits very few standard soil treatment systems. Galveston County should be permitting even less. Close attention should be paid to soil limitations, accepting as default drainage limitations unless proven otherwise.

## *Remediation of Failing OSSFs*

Short of hooking up the affected neighborhoods to central sewer lines, there are remedies for some of the existing failing septic systems. For soils that are saturated to or near the surface, mounded systems can be constructed that elevate the leach-field above the native soil (usually no more than about 2 feet). A surface spray system or a subsurface drip system could then be installed in the mound. An advanced treatment system before distribution would also be a chlorination and aeration treatment for surface spray application, or UV, ozonation or similar disinfection for subsurface drip application.

The main limitation would likely be space in some of the smaller lots. However, many of the lots in these areas are quite large making this a viable option for most sites. The cost would also be a factor. Where space is not a limitation, upgrading a standard system as described above might cost $5,000 per house.

## *Strategy*

- Detailed water sampling between failing OSSFs, tributaries, and Dickinson Bayou
- Hold a workshop (lecture and field exercise) on soil evaluation for Galveston County officials and OSSF installers and designers.
- Workshop on advanced retrofits for failing OSSFs

### *Expected Load Reduction*

Significant load reductions could be expected from fixing failing OSSFs. There is not sufficient data at this time, however, to specify what kind of load reductions could be expected from repair and/or replacement of failing systems.

### *Financial requirement*

- OSSF Feasibility study: $75,000
- OSSF Soil Evaluation Workshop: $5,000
- Advanced Retrofit Workshop: $10,000

### *Milestones*

- OSSF Feasibility study: 2010
- OSSF Soil Evaluation Workshop:  2009
- Advanced Retrofit Workshop: dependent on feasibility study

# 16. Strategies for Centralized Wastewater Treatment Facilities

## *Current Infrastructure*

The issue with permitted treatment facilities is not whether they are meeting their permit requirements as whether some of the older collection and treatment infrastructure is working as designed. In particular, some of the older sections of Dickinson are served by older pipes, such as clay pipes and asbestos-coated pipes that are subject to significant leakage, particularly in the high shrink-swell and wet soils that characterize much of this watershed. There is no data as to how much of the bacteria and CBOD problem in the Bayou might be attributed to faulty sewage infrastructure, there is no doubt that leakage from these older pipes is a significant problem to warrant attention. The principal wastewater treatment operator in the watershed, Water Control and Improvement District No. 1, is currently undertaking a program to upgrade all of the older pipes and several force mains[53]. The WCID #1 Board recently approved a nearly $17,000,000 improvement project to replace the older pipes within the next 8 years, largely financed through increased sewer rates. This replacement project will take place on a priority basis, addressing the areas with the greatest problems first. The areas of highest exfiltration or leakage appear to be between Gum Bayou and Hwy. 3.

## *Accidental Discharges*

Wastewater treatment plants are subject to occasional failures. Most treatment plants report these immediately and repair the problem in short order. Vigilant watershed citizens should be aware of unusual or foul smelling discharges into the bayou and report these immediately to TCEQ by calling 1-888-777-3186 or sending an e-mail to cmplaint@tceq.state.tx.us. A force main failure near Hwy 3 about 2 years ago resulted in a significant discharge directly into the Bayou and was noted by many citizens. WCID #1 has replaced and significantly upgraded the protection of that force main and is scheduled to replace a similar force main soon.

## *Illicit Discharges*

An illicit (illegal) discharge is defined as a discharge from a storm sewer system that is not entirely composed of stormwater. A discharge of domestic wastewater into a storm sewer system is perhaps the most common example of an illicit discharge Galveston County has an active monitoring program for illicit discharges, and published an important guidance manual on tracking illicit discharges[54].

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[53] Personal communication, David A Paulissen, General Manager, Galveston County WCID #1, January 29, 2009.
[54] A Guidance Manual for Identifying and Eliminating Illicit Connections to Municipal Separate Storm Sewer Systems (Galveston County (TX) Health District, 2002) http://www.gchd.org/pollution/GuideManual.pdf

## *The issue of fully permitted discharges and additional permits*

How much more wastewater could be discharged into the Bayou? The recent draft version of the Dickinson Bayou TMDLs[55] recommends a loading level no greater than 90% of the already existing and permitted load, in terms of CBOD. This includes, of course, a very substantial nonpoint or runoff source of CBOD pollution, which we are assuming comes mainly from potentially failing on-site septic systems. What this means is that the stream could absorb more loading—in fact, something more than about twice as much of an increase in the existing point-source load, barring any increase in the OSSF load. But that is just to maintain status quo –not achieve any improvements in stream and water quality. Full development of the watershed would much more than double the waste load—whether permitted point source or runoff. Clearly some choices and tradeoffs need to be made to insure the integrity of the bayou and its watershed in the future.

## *Milestones*

Complete conversion of clay sewer pipes: 2016 (sooner if additional funding is received)

[55] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

# 17. Site-Scale Strategies for Stormwater Management

Water quality issues for Dickinson Bayou are not only associated with permitted facilities such as municipal and industrial wastewater facilities but also derive from non-point source pollution. This pollution is caused by the everyday activities of watershed residents and is exacerbated by an increase in impervious surfaces (roads, parking lots, roof tops, driveways, etc.). Native soils in the watershed serve as a sponge that soaks up and filters rainwater and recharges ground water supplies. Paving over or building on open areas removes this natural sponge. Instead of soaking into the ground, water runs over concrete parking lots and, on to paved roads picking up pullutants as it flow over these surfaces; and into storm drains and into Dickinson Bayou and its tributaries, without the natural filtration of the soil.

Many of the tools listed below are referred to as Low Impact Development (LID) Best Management Practices (BMPs). They aim to mimic the natural hydrology of an area, allowing water to soak into the soil and as much as possible not run off. The design of these BMPs is site-specific and most are intended to be small scale projects that can easily be incorporated into a new or existing yard, parking lot or landscape.

## *Suggested Site Scale Stormwater Tools for the Dickinson Bayou Watershed*

**Rain Gardens**: Rain gardens offer a landscaping technique that can be applied to a variety of situations whether it is a commercial, public or residential setting. They are designed to capture runoff from impervious surfaces such as compacted lawns, roofs, sidewalks, streets or parking lots. The water is allowed to slow down, become filtered, and is absorbed into the soil, recharging ground water. The design is typically a bowl shaped garden, excavated slightly, and the soil amended with sharp sand and compost. Water is directed from a surface, like a roof, and pools for a short time. Any excess runoff enters the storm drain system, but is cleaned of 80% of contaminates. Because rain gardens are composed of native plants, they also attract wildlife such as birds and butterflies, providing a beautiful and functional addition to any landscape.

**WaterSmart Landscaping**: These landscapes are planted with native and adapted non-invasive plants. These are well suited to our climate and soil conditions; therefore, they require less watering once they are established and do not need chemical fertilizers, pesticides or herbicides to thrive. This can result in a 90% reduction in the amount of polluted runoff entering the storm drain system and an equal reduction in the volume of water used for irrigation. As an added feature, native plants attract wildlife such as birds and butterflies to our landscapes.

**Compost soil amendments:** Use of compost on residential and commercial landscapes can greatly reduce the need for soluble fertilizers and pesticides, more than any other practice. Some care should be exercised with composts derived wholly or mostly from animal manures.

**Bioswales**: These open, vegetated drainage ways have gradual slopes and collect and slowly move water downstream giving it a chance to soak into the ground before reaching the bayou. These can replace curb and gutter systems and are especially useful along road ways and parking lots. Swales can be planted with grass and maintained by mowing, or planted with low growing native wetland vegetation that can withstand both periods of moisture and drought and will not impede flow during large rain storms.

**Construction Site Compost Filters**: BMPs are not limited to post construction. Most construction sites are required to meet EPA standards for erosions and sediment control. Typically these sites employ silt fences and other structural practices, but there are better ways to address these issues. The best and, often times, most cost effective option is compost filters instead of control structures. After construction is completed, this compost can be spread out on site to help build healthy soil and establish lawns and flower beds.

**Rain Water Harvesting**: Water can be collected from roofs or hard surfaces (i.e. driveways or parking lots) and stored in small rain barrels or larger cisterns. This non potable water can be used to water plants and wash cars. Collecting water from hard surfaces keeps it from running into storm drains; by saving this water and distributing it during dryer times, it allows the water to soak into the soil and benefit from natural filtration before entering Dickinson Bayou.

**Watershed wide stormwater ordinances**: changing laws can make implementing BMPs more feasible in the watershed. This may simply mean changing the list of acceptable plants to include more natives (i.e. using native trees as street trees), allowing smaller driveways and parking lots to reduce impervious surfaces or allowing over flow lots to use pervious pavement. Especially as the communities within the watershed work to meet the requirements of MS4 permits. Small changes can make a large difference.

## *Ordinance*

A key component to the success of LID and stormwater BMPs in the Dickinson Bayou watershed is support from local governments. A post-construction stormwater ordinance should be written or amended for each city to encourage or require installation of BMPs for specific kinds of development.[56] Ordinance language should allow for easy installation and retrofit of stormwater BMPs. An example ordinance form the Center for Watershed Protection is provided in Appendix J. This contains important language on BMP design, construction and maintenance, as well as measures to address violations in all of these areas. It also suggests ways to incorporate runoff reduction criteria, and water quality criteria, so BMPs will help improve the water quality in Dickinson Bayou.

It is imperative that all of the municipalities have continuity between their stormwater ordinances. This does NOT mean every ordinance should be identical; however these can be written to meet the specific needs and concerns of each community, while keeping the health of the Dickinson Bayou watershed, Dickinson Bayou, and ultimately Galveston Bay as a main focus.

[56] Alternatively, a city could enact an ordinance restricting total loadings from developed areas, and leaving it to the developer as to how those loading requirements would be met.

## *Education*

Low impact development is a new concept to most citizens of the watershed including municipal officials and decision makers; therefore, a good educational program is essential for successful implementation of site specific BMPs. This program needs to reach stakeholders at every level within the watershed: students, homeowners, business owners, developers, elected officials and more. It will require different techniques and the efforts of many individuals and organizations to make this work. Efforts should include:

A **BMP Advisory Committee of technical experts will** be created. This committee will complete an informal survey of possible demonstration sites within the watershed and a list of recommended BMPs that are the most beneficial for the watershed. This group will also be available to local officials to answer questions and provide technical information about these strategies.

To reach the necessary individuals to make BMPs work, numerous **Workshops** are needed. These should focus on different groups including *municipal officials*, *developers* and *home owners*. It is essential to tailor each workshop to the audience and show them how they can implement site specific BMPs and how they can make a difference. These workshops should be held at appropriate times, to allow for optimal attendance. Also, it is best to schedule workshops for practices like rain gardens one to two months before optimal installation time so homeowners excited by the workshops are ready to implement these ideas at the correct time of year and will likely be more successful. The Texas AgriLife Extension Service will be a lead agency in holding workshops. Many additional groups, however, should also be involved, including but not limited to: All cities within the watershed, several branches of Galveston County government, Houston-Galveston Area Council, Master Naturalists, Master Gardeners, Galveston Bay Foundation, Galveston Bay Estuary Program, Texas Parks and Wildlife, local Universities, Texas Sea Grant, and Keep Dickinson Beautiful.

**Publications** are still one of the best ways to reach a mass audience. These can be distributed at community events, through schools or places of business. Publications can also be distributed electronically for very little cost. Publications explain the concept of BMPs are needed as well as a series of “How To” brochures for recommended BMPs so that developers, homeowners and business owners can “do it themselves.”

One of the best ways to inform people about site specific BMPs is through **Demonstration Sites,** or actual on the ground examples. The best way to teach someone is to show them. A demonstration of each BMP recommended by the advisory committee should be installed within the watershed. These should be in high profile, preferably public locations so they are easily accessed for viewing by anyone interested. Demonstration sites should also include interpretive signs explaining the site purpose, the techniques used, and why. These need to be colorful and inviting and use easily understandable language. Finally, once several of these demonstrations have been installed, a map and driving tour should be established and posted on local websites to facilitate tours for various groups.

Several **outreach programs** should be developed or implemented in the watershed. These could be spearheaded by any of the organizations mentioned in the workshop section above. Across the country the EPA, Extension Programs, Cities, Counties and States have put together excellent outreach campaigns targeting all types of non-point source pollution and use a variety of methods to reach the public. These should be implemented as is or tweaked to fit the needs of the Dickinson Bayou watershed. One such campaign should be targeted at *pet waste* as a source of bacteria and organic material. The Texas Commission on Environmental Quality and the EPA have developed some excellent information to work with and several additional pieces should be created to bring the necessary information to the watershed.

## *Expected Load Reduction*

In the short term, we expect to treat 250 acres of medium density development with BMPs, including at least two neighborhoods (if 60% of the homes install some form of BMP) as well as commercial areas. BMPs range in effectiveness from 30% to 90% depending on the type and design, so we assume an effectiveness of 60%. At this level, we expect to see a reduction of 437 lbs/yr (0.47%) for total phosphorus, 1,885 lbs/yr (0.47%) for total nitrogen and $5.5 \times 10^4$ billion colonies/yr for bacteria.[57]

In the long term, we expect to treat 10,000 acres of medium density development with BMPs. For the purpose of calculations, we again assume 60% participation and 60% effectiveness. At this level, we expect to see a reduction of 17,466 lbs/yr (18.7%) for total phosphorus, 75,395 lbs/yr (18.7%) for total nitrogen, and $2.2 \times 10^6$ billion colonies/yr (18.3%) for bacteria.[58]

## *Financial Requirement*

The cost to implement LID BMPs is very site specific; however it typically costs $5,000 to $10,000 per BMP. At an average of $7,500 per BMP it will cost around $1.1 million to install 150 BMPs in the Dickinson Bayou watershed. Below is a list of potential costs for each site as well as ways to minimize these costs.

The other costs are associated with education and production of publications. These will likely cost at least $250,000. Portions of these coats could be covered by local cities as part their compliance to MS4 permit guidelines.

[57] Complete calculations in Section 23
[58] Complete calculations in Section 23

*Table 12. Ways to minimize installation costs for BMPs*

| Potential Costs | Ways to minimize costs |
|---|---|
| • Site for locations<br>• Earth work<br>• Supplies<br>• Construction | • Volunteer labor<br>• Partnerships/cost sharing between agencies<br>• "Free" technical advice– through Extension Service and other programs |

## Milestones

- Creation of BMP Technical Committee: 2010
- List of the best BMP's for Dickinson: 2010
- Three construction site compost demonstration sites by: 2010
- Three additional BMP demonstrations completed at highly visible sites (selected from technical committee list): 2010
- Self guided tour map of demonstration sites in the watershed: early 2014
- Adoption of a watershed stormwater ordinance by all communities within the watershed: 2014
- 100 LID BMP's installed at private homes: 2014
- 50 LID BMP's installed at business, municipal offices, court houses, etc.: 2014
- Creation of (or retrofit) LID neighborhood: 2014
- 10,000 acres treated by BMPs: 2029

# 18. Strategies for Stormwater Detention and Wetlands

Wetlands are a key part of the Upper Texas Gulf Coast ecosystem and add to the subtle beauty of coastal prairies. They are also an integral part of the system that naturally cleans and detains stormwater as it makes its way to Galveston Bay. Engineers and biologists have found ways to design stormwater treatment wetlands into our stormwater detention and conveyance systems. These treatment wetlands are one of the very best options we have for cleaning polluted runoff. There are numerous sites in the watershed where engineered wetlands could be installed, and we know stormwater wetlands work in our area.[59]

Stormwater wetlands clean water much the same way as natural wetlands do. Wetland plants filter water as it passes through the marsh, and the chemical and biological processes unique to wetlands render many pollutants harmless, making the water exiting the wetland much cleaner than when it entered. A local example is the Mason Park Stormwater Wetland in Houston, Texas located along Brays Bayou. This wetland was designed to treat stormwater runoff from a 30 acre neighborhood while also providing habitat and beauty. The Mason Park wetland consistently removes 99% of bacteria from stormwater. This wetland has survived several severe floods and significant storm surge from a hurricane. It continues to provide all its design functions, especially improving water quality.

Stormwater wetlands can be incorporated in the Dickinson Bayou watershed in two ways. They can be retrofitted into existing stormwater detention ponds or they can be created from scratch in suitable locations.

### *Retrofit Wetlands*

The Dickinson Bayou watershed has many small stormwater detention areas which are often seen as eyesores that provide basic detention and little else. These could be retrofitted into stormwater wetlands, which will enhance the appeal of a site, provide basic detention and improve water quality. Two primary considerations dictate the shape and cost of retrofitting a stormwater wetland. First, the amount of land readily available for the wetland must be enough to adequately treat the volume of stormwater produced. Secondly, the overall performance goals of the wetland within the landscape need to be established before the wetland is created.

Detention basins already exist for most residential and commercial development; these sites are ideal locations to retrofit stormwater wetlands. For retrofits, a pond will likely need to be excavated and re-sculpted, but since the basic pond design already exists, the cost for this work is minimal. After the pond has been re-sculpted, native wetland plants should be installed to insure the full benefit of a treatment wetland. A variety of plants provide greater water quality benefits as well as habitat that draws birds and other wildlife to the wetland site.

[59] http://urban-nature.org/urbanwet/documents/e_coliarticle-master.pdf

## *New Construction Wetlands*

There are also opportunities to place larger stormwater wetland systems (similar to the Mason Park Stormwater Wetland) on publicly-owned property (i.e. parks) serving larger subwatersheds within the Dickinson Bayou watershed. These endeavors would be more costly up front, but provide a greater service over time and offer the possibility of a multiuse space that combines a wetland with a park, and creates precious habitat for wildlife.

The creation of a stormwater treatment wetland presents its own set of challenges. First, a site must be purchased. The size of the wetland will be determined by the tract of land available. Additionally, construction costs will be more than for a retrofit project because a pond must be dug and contoured, and stormwater pipes may need to be redirected into the wetland. One of the most costly components of digging a pond is the removal of soil and associated off-site disposal costs. On-site disposal will significantly lower the overall project cost.

## *Financial Requirements*

Cost per wetland can range from $30,000 to $50,000 per acre and up, exclusive of the land costs, depending on the site and size of the wetland. The first consideration starts with the land available for creation. Detention to compensate for runoff generated by a new development is required in this region. With planning, a typical dry detention basin could be replaced with a stormwater wetland. Choosing a stormwater wetland as both detention and treatment will require advance planning and design, and supplemental construction costs over and above what a simple detention basin would cost. A typical design can be produced for a retrofit or new construction for approximately $20,000 per wetland project. Additional costs may arise for engineering documents or plans, which will add approximately $10,000 to $20,000 to the total cost for design. Construction costs will vary by site depending on the location and whether disposal of fill material is on-site or off-site. Finally, the cost of vegetation and possibly water control structures need to be considered.

It is important to remember that the upfront cost needed to create a stormwater wetland treatment system will be recovered in long-term water quality improvement without additional expensive infrastructure.

## *Expected Load Reduction*

The initial short-term goal of stormwater wetlands is to treat approximately 250 acres of developed watershed land, which represents 1.3% of this land use type for the watershed. Using documented median removal rates for total suspended solids and bacteria, the expected load reduction is 1,257 lbs/yr (0.31%) for total nitrogen, 582 lbs/yr (0.62%) for total phosphate and $1.2 \times 10^6$ billion colonies/yr (1.1%) for bacteria.[60]

The long term goal is for all currently developed land (both medium and low density) to be treated by stormwater wetlands. Using the same removal rates as for the short-term goal, the

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[60] Complete calculations in section 23

expected load reduction is 267,968 lbs/yr of total nitrogen (32%), 96,634 lbs/yr of total phosphorus (23%) and 1.6 x $10^7$ billion colonies/yr (46%).[61]

## *Milestones*

- Develop a retrofit manual/guidebook for landowners: Fall 2009
- Complete 5 stormwater wetland treatment systems within the watershed: 2014
- All currently developed land treated by a stormwater wetland: 2029

[61] Reductions based upon projected 2029 loadings assuming full build out of the watershed at medium density, see section 23 for full calculations

# 19. Urban Growth Strategies

At full build out, an additional 100,000 new residents might be expected for the Dickinson Bayou watershed[62]. The current "recipes" for urban growth (the ordinances and codes that guide urban planning) allow and in fact insure that if growth continues unabated over the next 20-30 years, the entire watershed will be filled with suburban, automobile-dependent development, and, therefore, experience at least double the current pollutant loadings, given that the watershed is about 50% developed.

There are a couple of trends, however, that might slow this kind of growth. First is the rising cost of fuel. We can expect ups and downs in the price in the coming decades, but almost assuredly the overall price trend will be up, at times dramatically. People will be much less willing to drive long distances to work.

Second, changing demographics will result in large changes in demand for particular housing types over the next two decades.  A majority of home buyers will be families without children—aging empty nesters or singles and young families. Many of these people will be looking for low-maintenance homes in walking distance of shopping and restaurants. A recent study[63] suggests that we are already overbuilt within most of the country in terms of the single-family detached homes that will be in demand in 2030. If true, that result would not bode well for long term appreciation of housing stock in places like the Dickinson Bayou watershed, where there are many more residents than there are jobs, and where there are few neighborhoods that would attract the largest demographics over the next two decades.

An awareness is emerging that walkable neighborhoods and commercial districts are much more than a passing fad. Major new "town centers" are springing up across the region, from The Woodlands to Sugarland and even Pearland.  The main characteristics that make these developments walkable is proximity of the stores to each other and an urban pattern very much like older downtowns such as Galveston's The Strand or 6th Street in Texas City. Adjacent residential zones in a walkable community would have much smaller lots than are found in typical suburban developments, and much smaller setbacks to the street.  The Woodlands is building denser residential neighborhoods close to their town center, and somewhat walkable neighborhoods are emerging even in places like LaMarque (e.g., the Borondo Pines development).

The proximity of houses to businesses, and other community structures and places is what makes a place walkable. The environmental benefit of this proximity is that much less land is consumed per capita, land that can be preserved in its undeveloped state. For example, the average density of medium-density residential areas in the Dickinson Bayou watershed is about 2,000 people per square mile (roughly 2-3 units to the acre).  Residential areas a bit closer in to

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[62] A conservative estimate based on available land and current development densities.

[63] Nelson, A. C. 2006. Leadership in a new era. Journal of the American Planning Association, 72 (4):393-407.

Houston, for example in the Clear Lake area, have a density of about 4,000 people/ sq. mi. Eight thousand people per square mile (~8-10 units to the acre) is dense enough to yield a fairly walkable neighborhood, and still maintain detached single-family homes, although on relatively narrow lots (up to about 4,000 square feet). At 8,000 people/sq. mi., 100,000 people would occupy 12.5 square miles versus the 50 square miles occupied by development at 2,000 people/sq. mi. A denser development, of 12,000 people/ sq. mi., would result in further land savings. This would be similar to a townhome development.

Land savings are not the only environmental benefit to gain from walkable or compact development. Recent research[64] shows the total pollutant stormwater loads are much less for a given population at denser versus more spread out development. In fact, building a development at 8,000 people per square mile results in about the same reduction in pollutant loading that some of the best stormwater treatment practices (outlined in Section 18) could achieve treating runoff from a standard suburban development (4,000 people per square mile) for the same number of people.

Another benefit of compact traditional neighborhood development is the additional storm security associated with mixed-use developments.[65] Galveston's Strand, built in the classic mixed-use pattern of mixed commercial and residential, with compact residential neighborhoods within walking distance, survived the Great Storm of 1900 almost intact, and many more people could easily have taken refuge there had they known the extent of the approaching storm. Solidly-built mixed use commercial structures can act much like what FEMA calls a "safe-room", but at a community scale.

While the environmental benefits of small-town style compact development are considerable, the issue of community viability may be even more important to watershed residents. Many residents enjoy and will continue to demand larger-lot living, but every indication is that the very quality of life that drew them to this area will decay as the watershed builds out. The open spaces they enjoy will be gone, and strip malls will abound. Pockets of higher-density neighborhoods built around the small-town model could do more to preserve and even improve quality of life and the environment than just about any other practice. Figure 22 shows how a few select pockets could accommodate most of the forecast potential population increase, and Figures 23 shows what some of these density patterns might look like.

Compact growth in and of itself will not ensure that open space remains open. If there are areas worth preserving, then additional steps would need to be taken (discussed in Section 14).

Building at higher density might be the practice that could bring the highest total benefits for the watershed both in terms of environmental quality as well as quality of life, but it is clear that it is

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[64] Jacob, J.S. and R. Lopez. 2009. Is Denser Greener? An evaluation of higher density development as an urban stormwater best management practice, Journal of the American Water Resources Association. June 2009.

[65] Jacob, J.S. and S. Showalter.2008. The Resilient Coast: Policy frameworks for adapting the built Environment to climate change and population growth on the U.S. Gulf Coast. TAMU Sea Grant TAMU-SG-07-7401R. College Station.

also the most difficult practice to achieve. The current regulatory framework, for example, makes small-town density almost impossible to accomplish. A recent analysis of ordinances of all the municipalities in the watershed[66,67] revealed that a walkable, mixed-use development would require a series of variances, enough to discourage all but the most determined of developers.

A few simple changes, that would enable town-centered walkable development, could easily be made to most of the municipal ordinances in the watershed. Five simple changes are listed below. Changes in these areas would not require a major change in how development takes place, but could have a major impact on the shape that future development takes.

- *Smaller lots:* most municipalities in the watershed require 7000 sq. ft or more for single-family detached homes. Reducing the minimum to 3000-4000 sq ft would do more than just about anything else to improve walkability.
- *Greater density*: allowing more units to the acre is another way of expressing smaller lots. Eight to 12 dwelling units to the acre is dense enough to support a corner store or even light bus service, and still have single-family detached homes.
- *Mixed use*: Most modern zoning codes prescribe a separation of uses. Zoning can be a useful and powerful tool, but a too-strict separation of uses leads to auto-dependent development that is not at all walkable.
- *Reduce parking requirements*: recent studies have shown that most minimum parking requirements should probably be treated as maximum limits[68].
- *Greater street connectivity*: less cul de sacs and a higher number of intersections per square mile on a grid pattern enable higher density and much more walkability

There are many more areas that should be addressed to enable greener and more walkable development. The emerging LEED-ND standards provide a comprehensive list of areas to be addressed.[69]

An opportunity for denser, walkable development is presenting itself in the emerging I-45/ Hwy 3 commuter rail corridor. Transit-oriented-development is a special variety of town-centered development that occurs around transit stations. The rail stations could end up as large parking lots, but with a little foresight and some careful planning, these stations could be the location of some fairly vibrant urban neighborhoods that would contribute greatly to the overall quality of life in the area.

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[66] Kultgen, P. 2007. Dickinson Bayou Watershed Ordinance Compilation. Report to the Texas Coastal Watershed Program.
[67] Salzar, L. 2009. A Tool Kit for Texas Watershed Planning. An Analysis of Dickinson Bayou Watershed. Report to the Texas Coastal Watershed Program.
[68] Shoup, D.C. 2005. The High Cost of Free Parking. American Planning Association. Chicago, IL.
[69] Leadership in Energy and Environmental Design – Neighborhood Development; *www.usgbc.org/**LEED/ND***

## *Educational Component*

- Distribution of educational materials, including TCWP's Choices for Growth
- At least 3 growth related workshops, possibly related to HGAC's Liveable Centers concept, or Federal Highway Administration Context Sensitive Solutions workshops
- Preliminary public planning charrettes for transit stops if commuter rail discussion continues

## *Load reductions*

Compact growth will afford no load reductions from existing loadings, but we can expect load reductions for a set number of people for compact versus conventional development. Communities in the watershed may elect any number of compact growth scenarios. For a long-term load reduction scenario, we estimate 50 percent of all growth in the next 20 years (perhaps comprising about 50,000 people) on average could be as compact as 12,000 people per square mile. If that density resulted in a 40% reduction in nutrient loading versus conventional suburban development[70], then the total load reduction would be about 20% of the future additional load

## *Financial requirements*

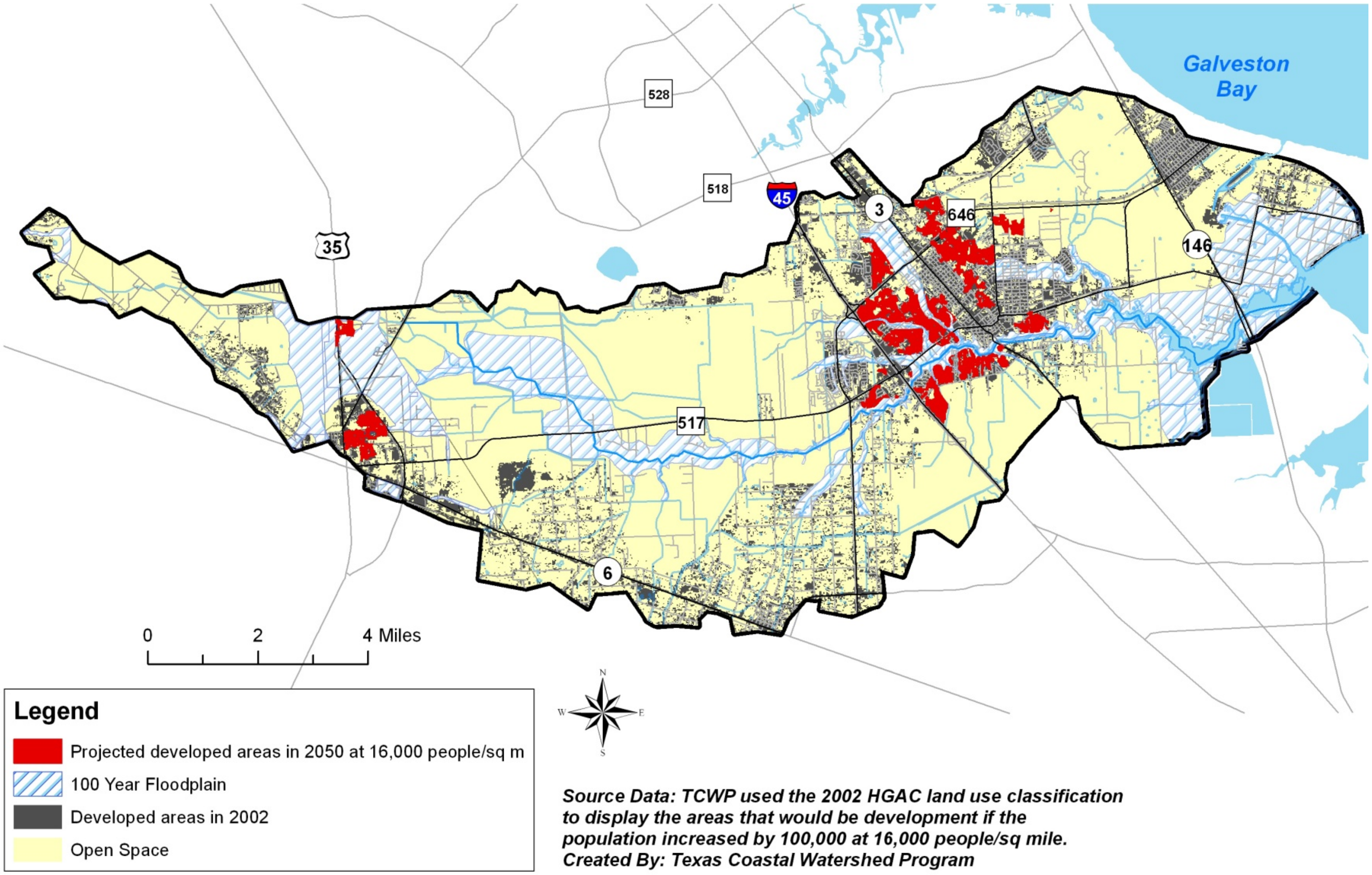
No additional financing would be necessary. With appropriate development ordinances in place, compact development should not cost any more than conventional development, and in fact should be cheaper per unit of development.

## *Milestones*

- Ordinance changes to allow compact growth in select areas: 2010
- At least 3 workshops, as outlined above: 2014

[70] Jacob, J.S. and R. Lopez. 2009. Is Denser Greener? An evaluation of higher density development as an urban stormwater best management practice, Journal of the American Water Resources Association. June 2009.

**Figure 22. Potential pockets of development with 100,000 additional watershed residents at 16,000 people per square mile (similar to the French Quarter of New Orleans)**




***Source Data: TCWP used the 2002 HGAC land use classification to display the areas that would be development if the population increased by 100,000 at 16,000 people/sq mile. Created By: Texas Coastal Watershed Program***

**Figure 23. Examples of what high density development can look like. Photos courtesy of Urban Advantage**


A typical modern mixed-use commercial district. Residential, commercial, and other uses are mixed and in close proximity. Cars are present, but this is not an “auto-dependent” neighborhood.


Single-family, detached homes dominate this compact, small-lot neighborhood. The greater concentration of houses enables some local retail within walking distance, and perhaps even some limited transit, not otherwise supportable in traditional larger lot communities.

# 20. Recreation and Parks Strategies

## *The Need for Parks*

The Dickinson Bayou watershed currently has 8.5 acres of park space for every 1,000 people. The National Recreation and Parks Association recommends a minimum of 10 acres of park space for every 1,000 people. The watershed is close to meeting this standard but still needs over 110 acres of park space to reach this minimum. One way to provide this park space is to create pocket parks on small parcels of existing city or county property, especially on land with bayou frontage. These small parks would provide park space for individual neighborhoods and also offer the potential for canoe and kayak launches or trail heads for walking trails along the bayou.

Small local parks also fit into the concept of livable centers and a walkable community[71]. (See also Section 19).

## *Connection to Habitat*

Adding park space, especially as nature parks, is a prime way to preserve habitat. This entails maintaining and managing land as it is and not creating mowed turf grass athletic fields. Parks can still be open for public use with walking trails, boardwalks, picnic tables and other amenities AND maintain the ecological function of the land.

This plan recommends preserving 4,200 acres of existing habitat in the watershed (See Section 14). Preserving habitat as nature parks allows for public access to these important natural resources and provides a framework for management of the property. These management techniques should strive to maintain ecological function and these parks should be dedicated through a land trust, conservation easement, or other agreement that will keep them as natural areas and not allow for the conversion to athletic fields or mowed turf areas.

Creating additional public access to the bayou is another multipurpose goal. Even small areas of water front property offer the opportunity for restoration of riparian (waters edge) habitat, either forest or marsh. The first priority for these areas should be as boat ramps, fishing piers, etc however we must consider multiple uses for all projects.

Regional detention basins offer another opportunity for parks. Centralizing detention (see Section 18) into large-scale (several hundred acres) sites offers another opportunity to access public lands. Instead of erecting fences and marking these areas as off-limits; walking trails, benches and even athletic fields can be worked into the design with the understanding that these areas will flood when necessary. The idea of a dual purpose facility is not new; Author Storey Park in Houston is a prime example of how, with planning, this is possible.

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[71] Shafer, S,, and Jacob, J. 2007. Urban Parks: The value of small urban parks, plazas, and other outdoor spaces. Department of Recreation, Parks, and Tourism Sciences, Texas A&M University, College Station. http://www.urban-nature.org/publications/documents/UrbanParks.pdf

### *Organic Landscaping Techniques for Park Management*

The management of existing and new park spaces is essential to mitigating non-point source pollution. Excessive nutrients in Dickinson Bayou are thought to be responsible in part of the low levels of oxygen. One major contributor to excessive nitrogen levels is chemical fertilizer. Parks are often large expanses of manicured lawns managed by mowing and fertilizing. An organic approach to management will reduce the amount of excess nitrogen that runs off of the land after the application of fertilizer as well as exposure of children to these chemicals on athletic fields.

### *Targeted Goals and Actions*

- Development of “pocket parks” for more accessibility to Dickinson Bayou.
- Improvement of existing public boat ramps.
- Clean up abandoned boats, barges and other debris in Dickinson Bayou
- Dredge the mouth of Dickinson Bayou to improve flow and oxygen exchange.
- Encourage greater water safety and boating safety measures in the local community in order to enhance local stewardship of the bayou.
- Encourage greater participation from local, state and federal authorities in enforcing water and boating safety measures on the bayou.
- Increase education on recreational activities and safety through signs and brochures on the watershed.

### *Financial Requirements*

With current land costs, it would cost $770,000 to purchase 110 acres of land. This land could be part of the 4,200 acres of preserved habitat. The City of Dickinson currently owns several small pieces of property along Dickinson Bayou that could possibly be developed into pocket parks with a small investment (less than $50,000) for signs, picnic tables, benches, trash cans, play equipment, parking, etc. There are grant funds available for park amenities that could be pursued by the city to help offset these expenses.

With park space there is also additional costs for maintenance. This expense would fall to counties or cities already working on shoestring budgets. Properly managing all parks in the watershed would likely mean a small tax increase or park usage fee. Switching to organic management techniques will require some additional funding up front but over time parks could begin their own compost programs, convert little used lawn areas to wildflower meadows to reduce mowing and incorporate other changes which would reduce long term maintenance costs.

### *Milestones*

- Add 50 acres of park space open to the public, portion of which will be pocket parks - 2013
- Installation of at least 5 educational signs throughout the watershed - 2011
- 25% of parks managed organically (using WaterSmart Landscaping principles) - 2014
- Hold 2 classes on boating safety and community stewardship - 2010
- Add 110 acres of park space open to the public – 2019
- 100% of parks managed organically (using WaterSmart Landscaping principles) - 2019

# 21. Water Quality Monitoring Plan

## *Historical and Current Monitoring*

Historical water quality monitoring data for Dickinson Bayou is limited[72]. Monitoring did not begin until 1992, with only one station collecting data (Station ID: 11467 Figure 24). Since that time, the Texas Commission on Environmental Quality has added twelve surface water quality monitoring stations along the bayou as well as a continuous monitoring station located at the bridge on State Highway 3 (Station ID: C733).

The TCEQ's Clean Rivers Program (CRP) is currently scheduled to monitor ten sites along Dickinson Bayou and its tributaries during fiscal year 2008/2009 (September 1, 2008 to August 31, 2009) under the supervision of the Houston-Galveston Area Council, with data collection being performed by the Environmental Institute of Houston (Table 13). During this time, surface water-quality samples will be collected quarterly at each of the ten sites. Parameters being collected include: dissolved oxygen, pH, temperature, conductivity, salinity, turbidity, total suspended solids, bacteria and flow.

According to the CRP Coordinated Monitoring Schedule, all or most of the monitoring stations listed below were monitored either quarterly or bimonthly from 2003 to 2008[73]. The data collected from the monitoring stations can be downloaded from the TCEQ Website[74].

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[72] Houston-Galveston Area Council. 2006. Basin Summary Report. Media: Interactive CD.
[73] Texas Commission of Environmental Quality Clean Rivers Program Coordinated Monitoring Schedule. 2009. <http://cms.lcra.org/>. Accessed 2009 January 31.
[74] www.tceq.state.tx.us

***Table 13: Frequency of Current Clean Rivers Program Surface Water Quality Sampling Fiscal Year 2009 (number of samples scheduled in Fiscal Year 2009)[75].***

| Station ID | Collection Agency* | Conventional | Bacteria | Flow | Field |
|---|---|---|---|---|---|
| **Segment: 1103 – Dickinson Bayou Tidal** | | | | | |
| 11434 | EIH | 4 | 4 | | 4 |
| 11436 | EIH | 4 | 4 | | 4 |
| 11455 | EIH | 4 | 4 | | 4 |
| 11460 | EIH | 4 | 4 | | 4 |
| 11460 | TCEQ | 4 | 4 | | 4 |
| 11462 | EIH | 4 | 4 | | 4 |
| 11464 | EIH/TCEQ | 4 | 4 | | 4 |
| 16469 | EIH | 4 | 4 | | 4 |
| 16470 | EIH | 4 | 4 | | 4 |
| 16471 | EIH | 4 | 4 | | 4 |
| **Segment 1104 – Dickinson Bayou Above Tidal** | | | | | |
| 11467 | EIH/TCEQ | 4 | 4 | 4 | 4 |

**EIH – Environmental Institute of Houston*
**TCEQ – Texas Commission of Environmental Quality*

## *Dissolved Oxygen TMDL*

As a result of the designation of non-attainment for DO criteria in the tidal portion of Dickinson Bayou in 1996, intensive monitoring was conducted as a part of the TMDL project to provide a baseline for TMDL model calibration. The TCEQ, in partnership with the Galveston County Health District, the Houston-Galveston Area Council and the U.S. Geological Survey conducted a series of monthly water quality monitoring events in 2000 and 2001. The effort consisted of 15 separate 48-hour DO surveys and water quality sampling events in seven locations and at two depths[76].

Intensive sampling conducted as part of the TMDL project confirmed that Dickinson Bayou is not meeting its assigned DO criteria and provided the detailed water quality information necessary to develop the TMDL[4].

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[75] *CRP Monitoring Schedule website.2008. <http://cms.lcra.org/schedule.asp?basin=11&FY=2009>*. Accessed February 2009.

[76] Texas Commission on Environmental Quality. 2008. Two Total Maxium Daily Loads for Dissolved Oxygen in Dickinson Bayou. Proposed for Public Comment.

## *Bacteria TMDL*

The University of Houston–main campus (U of H) and the consulting company CDM were contracted by TCEQ to provide data and information to characterize water quality conditions and to verify or discount impairments of the designated water body uses. U of H and CDM produced two reports to address ongoing concerns about high bacteria levels and fulfill the requirements of the Bacterial TMDLs:

1. TMDL for fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report, October 2007.

2. TMDL for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, February 2008.

Within the Sampling and Analysis Plan additional monitoring sites were established. These sites were strategically identified based on possible areas for increased pollutant loadings. Four components were established for additional research[77]:

1. Reconnaissance and pipe/source survey
2. Tributary monitoring
3. Bayou Wildlife Park monitoring
4. Waste water treatment plant monitoring

The Sampling and Analysis Plan (2008)[78] stated that they would sample at the outfalls of several unnamed tributaries to estimate tributary loadings, as well as locations surrounding the Bayou Wildlife Park and four waste water treatment plants.

The sampling locations were outlined in the TMDL for Fecal Bacteria in Dickinson Bayou Sampling and Analysis Plan. The sampling locations were proposed based on three main categories:

1. Proximity to tributaries to establish loadings from varying land uses
2. Potential loading from the Bayou Wildlife Park
3. The effect of waste water treatment plant effluent on water quality

All stations have been monitored for bacteria, water quality parameters (dissolved oxygen, pH, temperature, conductivity, salinity, and turbidity), instantaneous flow, nutrients (ammonia, total kjeldahl nitrogen, nitrite+nitrate, orthophosphorous, and total phosphorus), and conventional parameters (total suspended solids).

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[77] University of Houston and CDM. 2007. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report: Revision 1. pgs 121.
[78] Rifai, Hanadi. 2008. Total Maxium Daily Loads for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, Texas Commission on Environmental Quality.

***Table 14: List of Monitoring Sites for the Bacteria TMDLs (Modified from Rifai, (2008).[79]***

| Component | Station | Description | # Events | Collection Agencies | Parameters |
|---|---|---|---|---|---|
| Tributary | 11443 | Unnamed Tributary at Rymal Rd. | Up to 2 dry and 2 wet with 3-6 samples per wet event | U of H | Field, Bacteria, Nutrients, Conventional Flow |
| | TBD3[a] | Unnamed Tributary at Cowan Rd. | | | |
| | TBD4[a] | Unnamed Tributary at Avenue L | | | |
| | TBD2[a] | Unnamed Tributary at Algoa Friendswood Rd. | | | |
| Bayou Wildlife Park | 11464/11466[b] | Dickinson Bayou Near Arcadia/ Dickinson Bayou at Happy Hollow | Up to 2 dry and 2 wet (3-6 samples per wet event) | U of H | Field, Bacteria, BOD, Nutrients, Conventional Flow |
| | 11467 | Dickinson Bayou at FM517 | | | |
| WWTP Sampling | 4 WWTP[c] | See Table 7 | 1 event for a total of 4 WWTPs | To be determined | Field, Bacteria, Nutrients, Conventional Flow |

[a] *To be Determined. The sampling locations along the tributaries were not described at the time of this report.*
[b] *Either station 11464 OR 11466 was sampled based on site access during storm events.*
[c] *Four WWTP selected from Table 6 and Figure 12 were sampled based on compliance history, ability to access outfall and reconnaissance findings. These site locations and data have not been released prior to the publication of this Plan.*

## *Proposed Monitoring*

The Clean Rivers Program's surface water quality monitoring is scheduled to continue as stated in Table 14. No additional surface water quality monitoring is proposed other than the current CRP monitoring.

[79] Rifai, Hanadi. 2008. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, Texas Commission on Environmental Quality.

## *Targeted Goals*

- Continue Clean Rivers Program surface water quality monitoring
- Monitor water quality in all new stormwater treatment wetlands
- Install a new continuous water quality monitoring station with flow monitoring on Dickinson Bayou (to further investigate the problem of flow rates contributing to pollutant loading)

## *Financial Requirements*

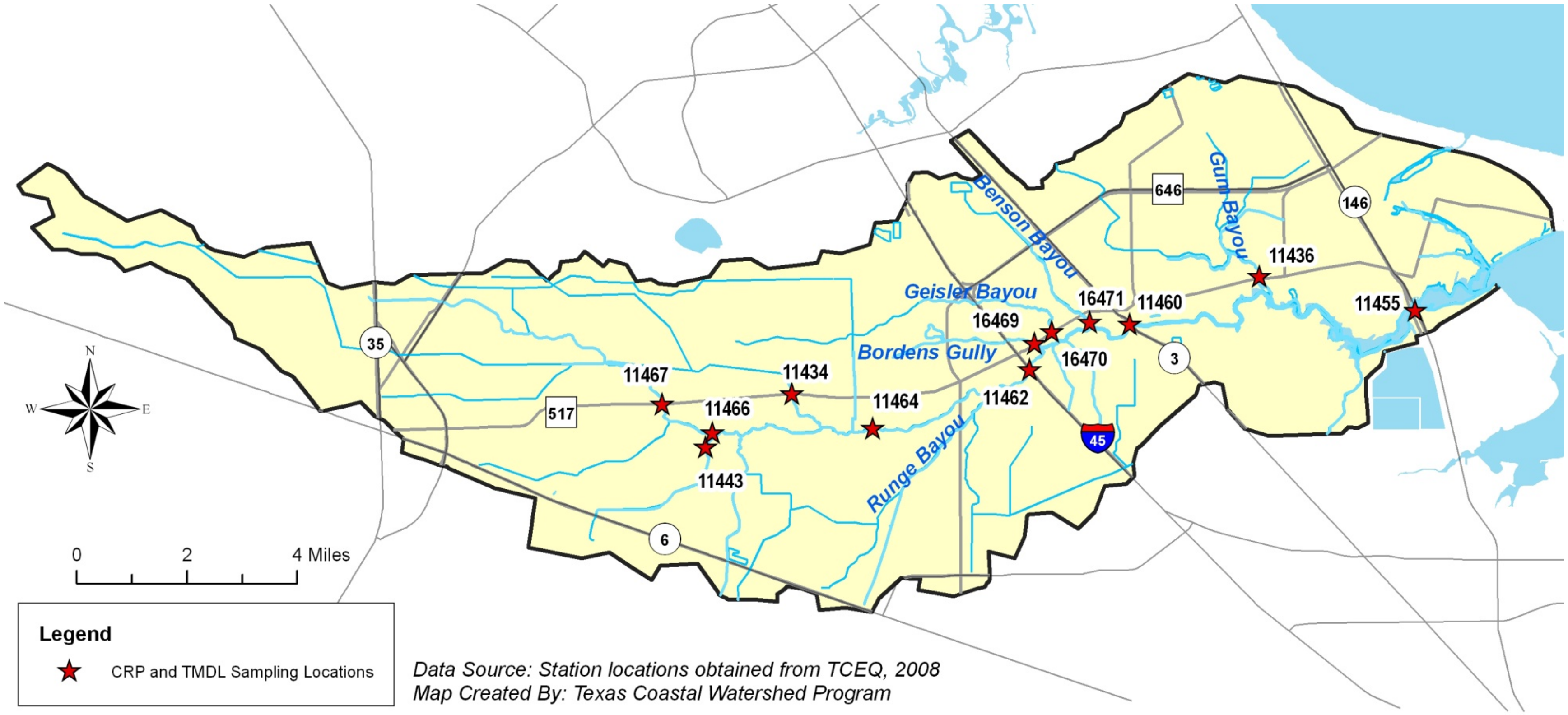
The Clean Rivers Program has already secured state funding of $22,000 to continue monitoring Dickinson Bayou. Stormwater wetland monitoring projects could potentially be integrated into the existing CRP monitoring program for minimal costs, about $1,000 per site, per year. However, it will provide more useful data to install automated monitors on at least some wetlands sites that cost upwards of $10,000 each.

The continuous water quality monitoring station will cost between $10,000 and $20,000 a year including installation and upkeep costs. The United States Geologic Survey and TCEQ have a co-op program that is a realistic option for funding this monitoring station.

## *Milestones*

- Long term water quality data set from CRP: 2014
- Installation of continuous water quality monitoring station with flow monitor: 2014
- All stormwater treatment wetlands monitored though CRP or equipment: 2029

**Figure 24. Current Clean Rivers Program and Bacteria TMDL Water Quality Sampling Stations**



# 22. Pollutant Loadings

We developed a series of pollutant loading calculations to roughly quantify the impacts of the strategies selected in this plan on reducing existing and future pollutant loadings in the watershed. These calculations were based on the Simple Method developed by the Center for Watershed Protection. The Simple Method[80] for calculating loadings allows loads to be broken down by land use type. This method also allows the use of local data for pollutant concentrations, making the numbers more specific to the Dickinson Bayou watershed. The Simple Method is similar to the well-known Curve Number method, except that it uses impervious cover percentage values rather than curve numbers based on soil types. As input for the Simple Method calculations outlined here, we used imperviousness values from the Galveston County Consolidated Drainage District Drainage Criteria Manual[81] and EMC values from a detailed non-point source characterization done for the Galveston Bay National Estuary Program in 1992[82]. The 1992 study used the curve number rather than the Simple Method to calculate pollutant loadings for watersheds contributing to Galveston Bay, including that of Dickinson Bayou.

**L = Annual Load (lbs/year) = 0.226 * R * C * A** (for chemical constituents)

**L = Annual Load (lbs/year) = 0.00103 * R * C * A** (for bacteria)

0.226 = unit conversion factor (chemical constituents)

0.00103 = unit conversion factor (for bacteria)

R = annual runoff (inches) = P * Pj * Rv

P = Annual rainfall (45 inches)

Pj = Fraction of annual rainfall events that produce runoff (0.9)

Rv = Runoff coefficient (calculated as 0.05 + 0.9*Ia)

Ia = Impervious Cover (69% for medium density development, and 13% for low density development, 0% for open space, Table 15)

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[80] The Stormwater Managers Research Center, http://www.stormwatercenter.net (under “By Category”, then “Simple Method”

[81] Galveston County Consolidated Drainage District Drainage Criteria Manual, 2004.

[82] Values taken from Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.

C = Pollutant concentration/Event Mean Concentration (mg/l)[83]

A = Area (acres)

## *Current Loadings*

***Table 15. Impervious Cover for TCWP Land Use Loadings for the Dickinson Bayou Watershed (Taken from Galveston County Consolidated Drainage District Criteria Manual[84])***

| TCWP Classification | GCCDD Classification | Percent Impervious Value | Averaged Percent Value[85] |
|---|---|---|---|
| Medium Density | High Density | 85 | 69 |
| | Residential Small Lot | 40 | |
| | Isolated Transportation | 90 | |
| | Light Industrial | 60 | |
| Low Density | Residential Large Lot | 20 | 13 |
| | Residential Rural Lot | 5 | |
| | Developed Green Acres | 15 | |
| Open Space | Undeveloped | 0 | 0 |

[83] Values taken from Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[84] Galveston County Consolidated Drainage District Drainage Criteria Manual, 2004.
[85] Value used in loading calculations below

*Table 16. Current Total Phosphorus Loadings*

| | Medium Density Development | Low Density Development | Open Space | Entire Watershed |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.226 | --- |
| **R (annual runoff, inches)** | 27.18 | 6.76 | 2.03 | --- |
| **C (pollutant concentration, mg/l)** | 0.79[a,b] | 0.42[a,c] | 0.12[a,d] | --- |
| **A[e] (area, acres)** | 19,267 | 13,467 | 33,563 | 66,270 |
| **L (annual load, lbs/year)** | **93,482** | **8,646** | **1,842** | **103,969** |
| **L (annual load, kg/year)** | **34,891** | **3,227** | **687** | **38,805** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as "Residential" Table 5.11 pg 93
[c] Average of "Residential," "Agricultural," and "Open/Pasture" values in Table 5.11 pg 93
[d] Value labeled as "Open/Pasture" in Table 5.11 pg 93
[e] From TCWP land use map (Figure 14)

*Table 17. Current Total Nitrogen Loadings*

| | Medium Density Development | Low Density Development | Open Space | Entire Watershed |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.226 | --- |
| **R (annual runoff, inches)** | 27.18 | 6.76 | 2.03 | --- |
| **C (pollutant concentration, mg/l)** | 3.41[a,b] | 2.16[a,c] | 1.51[a,d] | --- |
| **A[e] (area, acres)** | 19,267 | 13,467 | 33,563 | 66,270 |
| **L (annual load, lbs/year)** | **403,510** | **44,464** | **23,175** | **471,149** |
| **L (annual load, kg/year)** | **183,194** | **20,186** | **10,521** | **213,902** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as “Residential” Table 5.11 pg 93
[c] Average of “Residential,” “Agricultural,” and “Open/Pasture” values in Table 5.11 pg 93
[d] Value labeled as “Open/Pasture” in Table 5.11 pg 93
[e] From TCWP land use map (Figure 14)

*Table 18. Current Bacteria Loadings*

| | Medium Density Development | Low Density Development | Open Space | Entire Watershed |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.00103 | 0.00103 | 0.00103 | --- |
| **R (annual runoff, inches)** | 27.18 | 6.76 | 2.03 | --- |
| **C (pollutant concentration, mg/l)** | 22,000[a,b] | 9,000[a,c] | 2,500[a,d] | --- |
| **A[e] (area, acres)** | 19,267 | 13,467 | 33,563 | 66,270 |
| **L (annual load, billion colonies/year)** | **$1.1 \times 10^7$** | **$8.4 \times 10^5$** | **$1.7 \times 10^5$** | **$1.3 \times 10^7$** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as “Residential” Table 5.11 pg 93
[c] Average of “Residential,” “Agricultural,” and “Open/Pasture” values in Table 5.11 pg 93
[d] Value labeled as “Open/Pasture” in Table 5.11 pg 93
[e] –TCWP land use map (Figure 14)

## *1992 Loadings*

As a cross check on our Simple Method calculations, we calculated loadings for Dickinson Bayou in 1992 using the 1992 input values. Except for bacteria, our calculated values were within rough agreement with the values developed with curve numbers and published in the 1992 report.

*Table 19. Total Phosphorus Loadings using 1992 data*

| | **Medium Density Development** | **Low Density Development** | **Agriculture** | **Entire Watershed** |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.226 | --- |
| **R (annual runoff, inches)** | 27.2 | 16.6 | 2.0 | --- |
| **C (pollutant concentration, mg/l)** | 0.37[a,b] | 0.790[a,c] | 0.36[a,d] | --- |
| **A[a,e] (area, acres)** | 3,200 | 5,760 | 12,800 | --- |
| **L (annual load, kg/year)** | **3,301** | **7,753** | **957** | **12,011** |
| **GBNEP Calculated Load[a,f] (kg/year)** | **---** | **---** | **---** | **21,000** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

*Table 20. Total Nitrogen Loadings using 1992 data*

| | Medium Density Development | Low Density Development | Agriculture | Entire Watershed |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.226 | --- |
| **R (annual runoff, inches)** | 27.2 | 16.6 | 2.0 | --- |
| **C (pollutant concentration, mg/l)** | 2.1[a,b] | 3.41[a,c] | 1.56[a,d] | --- |
| **A[a,e] (area, acres)** | 3,200 | 5,760 | 12,800 | --- |
| **L (annual load, kg/year)** | **18,737** | **33,464** | **4,149** | **56,350** |
| **GBNEP Calculated Load[a,f] (kg/year)** | **---** | **---** | **---** | **130,000** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

*Table 21. Bacteria Loadings using 1992 data*

| | Medium Density Development | Low Density Development | Agriculture | Entire Watershed |
|---|---|---|---|---|
| **Unit Conversion Factor** | 0.00103 | 0.00103 | 0.00103 | --- |
| **R (annual runoff, inches)** | 27.2 | 16.6 | 2.0 | --- |
| **C (pollutant concentration, mg/l)** | 22,000[a,b] | 22,000[a,c] | 2,500[a,d] | --- |
| **A[a,e] (area, acres)** | 3,200 | 5,760 | 12,800 | --- |
| **L (annual load, billion colonies/year)** | **$2.0 \times 10^6$** | **$2.2 \times 10^6$** | **$6.7 \times 10^4$** | **$4.2 \times 10^6$** |
| **GBNEP Calculated Load[a,f] (billion colonies/year)** | **---** | **---** | **---** | **$6 \times 10^6$** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

## *Projected Load Reductions*

### *Stormwater Best Management Practices*

***Table 22. Projected load reductions for installation of site specific BMPs; this includes residential and commercial areas. We assume 60% participation and 60% BMP effectiveness.***

| | **Projected Load Reductions for Short Term Goals (5 years)** | | | **Projected Load Reductions for Long Term Goals (20 years)** | | |
|---|---|---|---|---|---|---|
| | **Total Phosphorus** | **Total Nitrogen** | **Bacteria** | **Total Phosphorus** | **Total Nitrogen** | **Bacteria** |
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.00103 | 0.226 | 0.226 | 0.00103 |
| **R (annual runoff, inches)** | 27.18 | 27.18 | 27.18 | 27.18 | 27.18 | 27.18 |
| **C[a] (pollutant concentration, mg/l)** | 0.79 | 3.41 | 22,000 | 0.79 | 3.41 | 22,000 |
| **A (area, acres)** | 250 | 250 | 250 | 10,000 | 10,000 | 10,000 |
| **Percent participation** | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| **Percent effectiveness** | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| **Annual Load Reduction** | **437 lbs** | **1,885 lbs** | **$5.5 \times 10^4$ billion colonies** | **17,466 lbs** | **75,395 lbs** | **$2.2 \times 10^6$ billion colonies** |
| **Annual Percent Load Reduction** | **0.47%** | **0.47%** | **0.5%** | **18.7 %** | **18.7%** | **18.3%** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX. Value labeled as “Residential” Table 5.11 pg 93

[b] Center for Watershed Protection. 2007. National Pollutant Removal Performance Database, Version 3.

### *Stormwater Wetlands*

***Table 23. Projected load reductions for installation of storm water wetlands. Short term load reductions are calculated for treatment of 250 acres of medium density development. Long term reductions are calculated for treatment of all currently developed lands (both medium and low density).***

| | **Projected Load Reductions for Short Term Goals (5 years)** | | | **Projected Load Reductions for Long Term Goals (20 years)** | | |
|---|---|---|---|---|---|---|
| | **Total Phosphorus** | **Total Nitrogen** | **Bacteria** | **Total Phosphorus** | **Total Nitrogen** | **Bacteria** |
| **Unit Conversion Factor** | 0.226 | 0.226 | 0.00103 | --- | --- | --- |
| **R (annual runoff, inches)** | 27.18 | 27.18 | 27.18 | --- | --- | --- |
| **C[a] (pollutant concentration, mg/l)** | 0.79 | 3.41 | 22,000 | --- | --- | --- |
| **A (area, acres)** | 250 | 250 | 250 | 32,734 | 32,734 | 32,734 |
| **Percent effectiveness** | 0.48 | 0.24 | 0.78 | 0.48 | 0.24 | 0.78 |
| **Annual Load Reduction** | **582 lbs** | **1,257 lbs** | **$1.2 \times 10^6$ billion colonies** | **49,021 lbs** | **107,514 lbs** | **$1.0 \times 10^7$ billion colonies** |
| **Annual Percent Load Reduction** | **0.62%** | **0.31%** | **1.1%** | **48%** | **24%** | **78%** |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX. Value labeled as "Residential" Table 5.11 pg 93

[b] Value taken from Center for Watershed Protection. 2007. National Pollutant Removal Performance Database, Version 3.

## *Habitat*

***Table 24. Projected load reductions from preserving land in a natural state, preventing this land from being developed. Calculations assume land would be developed at Medium Density, the most common density in the watershed. Stopping development would stop loadings from increasing by these amounts each year.***

| | Projected Load Reductions for Short Term Goals (5 years) | | | | | | Projected Load Reductions for Long Term Goals (20 years) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Phosphorus | | Total Nitrogen | | Bacteria | | Total Phosphorus | | Total Nitrogen | | Bacteria | |
| | Open Space | Medium Density | Open Space | Medium Density | Open Space | Medium Density | Open Space | Medium Density | Open Space | Medium Density | Open Space | Medium Density |
| Unit Conversion Factor | 0.226 | 0.226 | 0.226 | 0.226 | 0.00103 | 0.00103 | 0.226 | 0.226 | 0.226 | 0.226 | 0.00103 | 0.00103 |
| R (annual runoff, inches) | 2.03 | 27.18 | 2.03 | 27.18 | 2.03 | 27.18 | 2.03 | 27.18 | 2.03 | 27.18 | 2.03 | 27.18 |
| C[a] (pollutant concentration, mg/l) | 0.12[a,b] | 0.79[a,c] | 3.41[a,b] | 3.41[a,c] | 2,500[a,b] | 22,000[a,c] | 0.12[a,b] | 0.79[a,c] | 3.41[a,b] | 3.41[a,c] | 2,500[a,b] | 22,000[a,c] |
| A (area, acres) | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 4,200 | 4,200 | 4,200 | 4,200 | 4,200 | 4,200 |
| Load | 55 | 4,852 | 691 | 20,943 | $5.2 \times 10^3$ | $6.2 \times 10^5$ | 231 | 20,381 | 2,902 | 87,961 | $2.2 \times 10^4$ | $2.6 \times 10^6$ |
| Annual Load Reduction | 4,797 lbs | | 20,252 lbs | | $6.2 \times 10^5$ billion colonies | | 20,147 lbs | | 85,059 lbs | | $2.6 \times 10^6$ billion colonies | |
| Annual Percent Load Reduction | 4.6% | | 4.3% | | 4.7% | | 19.4% | | 18.1% | | 19.7% | |

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as “Open/Pasture” in Table 5.11 pg 93
[c] Value labeled as “Residential” Table 5.11 pg 93