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Chapter 5 – Impacts of Water Management Strategies on Key Parameters of Water Quality and Impacts of Moving Water from Rural and Agricultural Areas

5.1 Scope of Work

This planning effort is part of a consensus-based planning effort to include local concerns in the statewide water supply planning effort. This chapter presents the results of Task 5 of the project scope, which addresses:

- Impacts of Water Management Strategies on Key Parameters of Water Quality
- Evaluation of Third-Party Impacts of Reduced Levels in Water Supply Reservoirs
- Impacts of Moving Water from Rural and Agricultural Areas.

5.2 Impacts of Water Management Strategies on Key Parameters of Water Quality

The potential impacts that water management strategies may have on water quality are discussed in this section, including the identified water quality parameters which are deemed important to the use of the water resources within the region. Under the Clean Water Act, Texas must define designated uses for all major water bodies and, consequently, the water quality standards that are appropriate for that designated water body use. The water quality parameters which are listed for Region H below were selected based on the *TCEQ Water Quality Inventory for Designated Water Body Uses* as well as the water quality parameters identified in the Texas Commission on Environmental Quality (TCEQ) 303d list of impaired water bodies. For reference purposes, *Appendix 5A* contains the TCEQ 303d list of impaired waters within the region and the tabular summaries of use support for the water bodies that are part of Region H.

Key surface water parameters identified within Region H fall into two broad categories:

Nutrients and non-conservative substances:

- Bacteria
- pH
- Dissolved Oxygen
- Total Suspended Solids (TSS)
- Temperature
- Nutrients (Nitrogen, Phosphorus)

Minerals and conservative substances:

- Total Dissolved Solids (TDS)
- Chlorides

- Mercury
- Salinity
- Sediment Contaminants

Non-conservative substances are those parameters that undergo rapid degradation or change as the substance flows downstream, such as nutrients which are consumed by plant life. Nutrient and non-conservative loading to surface water originates from a variety of natural and man-made sources. One significant source of these loads is wastewater treatment facilities. As population increases, the number and size of these wastewater discharges will likely increase as well. Stormwater runoff from certain land use types constitutes another significant source of nutrient loading to the region's watercourses, including agricultural areas, golf courses, residential development, or other landscaped areas where fertilizers are applied. Nutrient loads in Region H are typically within the limits deemed acceptable for conventional water treatment facilities, and are therefore not considered a major concern as related to source of supply.

Conservative substances are those that do not undergo rapid degradation or do not change in water as the substance flows downstream, such as metals. Mineral and other conservative substance loading to surface water generally originates from three sources: (1) non-point source runoff or groundwater seepage from mineralized areas, either natural or man-made (2) wastewater discharges, and (3) sea water migration above estuaries. Region H is fortunate in that the first category is not typical of this area except for the Brazos River which has several natural salt-contributing areas; fortunately, flows in the lower basin generally are sufficient to dilute these sources to easily manageable concentrations. Wastewater discharges, and industrial discharges in particular, have improved over the past 30-years due to the requirements of the Clean Water Act. If local concentrations of conservative contaminants are identified, they are remediated by the appropriate agency. Salinity migration above estuaries is controlled in the Trinity River by the Wallisville Saltwater Barrier, and in the San Jacinto River by the Lake Houston Dam. The 2006 Region H Plan and the 2011 update of the Plan recommends a saltwater barrier be added above the Brazos estuary to protect water quality in that reach of the Brazos River as well. Sediment contaminants can provide particulate matter that can encourage the growth of blue-green algae (cyanobacteria). Sand mining, in particular, has lead to increased nutrient loads in the San Jacinto River which can result in an increase in cyanobacteria levels.

Groundwater in Region H is generally of good quality with no usage limitations. Quality parameters of interest include Total Dissolved Solids (TDS), metals and hardness. Portions of the Carrizo-Wilcox aquifer can contain levels of iron that require sequestering or removal through treatment facilities. The Brazos River Alluvium is directly recharged from the based flow in the Brazos River, and has the potential to reflect any contaminant loading of the Brazos River. Portions of the aquifer currently experience elevated TDS and hardness.

Water quality of the Gulf Coast aquifer is generally good throughout the Region. The Chicot and Evangeline aquifers are capable of yielding moderate to large amounts of fresh water in most of the Region. Fresh water is overlain and underlain by saline water in coastal areas and the coastal deposits are not capable of yielding fresh water. Deeper formations throughout the region are able to supply limited freshwater and slightly saline water in updip areas.

Some localized sites within the Region have the potential to cause contamination of the aquifer under adverse conditions. These sites once generated surface water pollution which, if not properly handled, could cause contamination of local soils or shallow groundwater supplies. Except for the northern areas of the Region, the thickness of the near-surface clay soils located over much of the Region provide an effective barrier to deeper aquifer contamination due to normal infiltration. As a consequence, the primary risk for Gulf Coast aquifer groundwater contamination occurs if there are improperly designed or inadequately sealed wells which are exposed to this surface contamination. Localized shallow alluvial aquifers primarily located along the major streams such as the Brazos River are at greater risk for contamination from these sites as a result of the more direct travel paths for potential contaminated water to reach these areas, especially if they are being pumped by small household or livestock wells. At this time, there are no recorded incidents of contaminated groundwater in the Region as a result of these sites.

The water quality parameters and water management strategies selected by the RHWPG were evaluated to determine the impacts on water quality as a result of these recommended strategies. This evaluation used the data available to compare current conditions to future conditions with Region H management strategies in place. The recommended and alternative management strategies, as described in *Chapter 4* of this report and used in this evaluation, are listed below.

Recommended Water Management Strategies

Conservation Strategies:

- Industrial Conservation
- Irrigation Conservation
- Municipal Conservation

Contractual Strategies:

- Expand/Increase Current Contracts
- New Contracts from Existing Supplies
- Reallocation of Existing Supplies
- TRA to SJRA Contract
- TRA to Houston Contract
- WUG-Level Contracts[1]
- WWP Contracts

Groundwater Strategies:

- Expanded Use of Groundwater
- Interim Strategies
- New Groundwater Wells for Livestock

Groundwater Reduction Plans:

- CHCRWA GRP
- COH GRP
- City of Missouri City GRP
- Fort Bend MUD 25 GRP
- Fort Bend WCID 2 GRP
- NFBWA GRP[2]
- NHCRWA GRP[2]
- Pecan Grove GRP
- Richmond/Rosenberg GRP
- River Plantation GRP
- SJRA WRAP[3]
- Sugar Land GRP
- WHCRWA GRP[2]

Infrastructure Strategies:

- CHCRWA Transmission Line
- CHCRWA Internal Distribution
- CLCND West Chambers System
- COH Distribution Expansion
- COH Treatment Expansion
- Harris County MUD 50 WTP
- Huntsville WTP
- LLWSSSC Surface Water Project

Luce Bayou Transfer

NFBWA Internal Distribution

NFBWA Shared Transmission Line

NHCRWA Internal 2010 Distribution

NHCRWA Internal 2020 Distribution

NHCRWA Internal 2030 Distribution

NHCRWA Transmission 2010

NHCRWA Transmission 2020

NHCRWA Transmission 2030

Pearland SWTP

Sealy GW Treatment Expansion

WHCRWA Internal Distribution

WHCRWA Transmission Line

Reservoir Strategies:

Allens Creek Reservoir

Brazoria County Off-channel Reservoir

Dow Off-Channel Reservoir

Fort Bend County Off-channel Reservoir

GCWA Off-channel Reservoir

Reuse Strategies:

Fulshear Reuse

Houston Indirect Reuse

Montgomery MUD 8/9 Indirect Reuse

NHCRWA Indirect Reuse

Wastewater Reuse for Industry

Wastewater Reclamation for Mun. Irrigation

Permit Strategies:

BRA System Operations Permit

Houston Bayous Permit

Other Strategies:

Brazoria Co. Interruptible Supplies for Irr.

Freeport Desalination Plant

Brazos Saltwater Barrier

Alternative Water Management Strategies

Montgomery MUD 8/9 Brackish Water Desalination

Sabine to Region H Transfer

Little River Off-channel Reservoir

The following paragraphs discuss the impacts of each management strategy on the chosen water quality parameters.

Increased Groundwater Usage, including Expanded Use of Groundwater, Interim Groundwater, and New Groundwater Wells, is not expected to have significant environmental effects. Groundwater within the Region is generally of good quality and available at the point of use. Increases in well pumping will also contribute to return flows in all river basins in Region H. The return flows will increase in proportion to increased groundwater use and significantly contribute to flows into Galveston Bay. Increased and interim groundwater pumping in the region will continue to be monitored by groundwater regulatory agencies since excessive pumping can lead to land subsidence and exacerbate flooding and drainage problems.

Water Conservation, including municipal, industrial, and agricultural conservation, can have both positive and negative impacts on water quality. Water that is being processed through a wastewater treatment plant typically has acquired additional dissolved solids prior to discharge to the waters of the state. Conventional wastewater treatment reduces suspended solids, but does not reduce dissolved solids in the effluent. Water conservation measures will reduce the volume of water passing through the wastewater plants without reducing the mass loading rates (a 1.6 gallon flush carries the same waste mass to the plant that a 6-gallon flush once carried). This may result in slightly increased conservative contaminant loads in the stream. However, it should be noted that during low flow conditions, the wastewater effluent in a stream may represent water that helps to augment and maintain the minimum stream flows. Tail water is the term used to describe that water returned to the stream after application to irrigated cropland. Tail water carries nutrients, sediments, salts, and other pollutants from the farmland. This return flow can have a negative impact on water quality, and by implementing conservation measures which reduce tail water losses, the nutrient and sediment loading can be reduced. Once again, however, this return flow tends to be introduced into the receiving stream during normally dry periods so it may have a net beneficial effect in terms of maintaining minimum stream flow conditions. Furthermore, the loss of the return flows could be offset by a reduction in irrigation diversions resulting in no net affect on the stream flow.

BRA System Operations strategy potentially impacts the water quality in the lower basin depending on the actual diversion quantities and diversion locations. The BRA will develop a management plan for implementing its System Operations Permit. The management plan will address actual operations under the System Operations Permit, including water quality considerations. Decreased instream flows directly influence saltwater intrusion, which may be mitigated by a saltwater barrier. However, in the "Report in Support of System Operation Permit Application" prepared by Freese and Nichols, Inc. for the BRA, it is stated that system operations would not negatively impact instream flows and may increase the frequency of meeting instream criteria in many locations. Because many of the existing impaired segments within the Brazos Basin are located above system reservoirs, it was also found that the hydrology of these segments will not be significantly impacted by the BRA System Operations.

Although the maximum diversions anticipated under the system operations conditions may pose some slight impact on estuary conditions, the frequency of occurrence for these actual diversions is very low. Additionally, since the Brazos River empties directly into the Gulf of Mexico, operational changes will not affect a large bay system but may impact flows into the Brazos River Estuary and the Columbia Bottomlands. Changes to flow patterns will likely be localized and fall within historical parameters. In conclusion, the BRA's analysis recognized the System Operations Permit to be more environmentally sensitive than other potential strategies including new reservoir construction, groundwater resource development, and importing water supplies from outside the basin.

The Brazos Saltwater Barrier would help maintain water quality in the lower Brazos basin during low flow periods. Currently, during low flow periods the Dow Chemical and Brazosport Water Authority lower intakes are compromised due to saltwater intrusion. Increased use of Brazos River supplies will extend this seasonal condition upstream unless a barrier or other control measure is implemented.

Freeport Desalination does not affect other water management strategies and affects only the salinity levels in the area of discharge. The discharge water will blend with and be diluted by other water before flowing into the Brazos River above the Intracoastal Waterway. The diversion of Brazos River water to supplement seawater supplies to the desalination plant would maximize the operational efficiency, but could increase the salinity of the Brazos River Estuary, depending upon the size and season of the diversion.

Allens Creek Reservoir, Brazoria County Off-channel Reservoir, Fort Bend County Off-channel Reservoir, Dow Off-channel Reservoir and Little River Off-channel Reservoir will modify downstream flow regimes, but potentially have positive impacts on water quality. The impacts will be investigated further once a flow regime is developed for the Brazos River. These off-channel reservoirs will be operated as "scalping reservoirs". During times of high flow, water quality in the Brazos River is often poor in terms of suspended solids due to increased sediment loads. At the same time, that water is of better quality in terms of dissolved solids concentrations since the salt being introduced into the Brazos in its upper reaches is diluted. The water that is diverted and stored in reservoirs would allow sediments to settle and accordingly water released from the reservoir would potentially have less sediment concentration. However, reduced sediment loads may have negative impacts on habitats relying on sediments downstream of the proposed reservoirs. Nutrients such as nitrogen and phosphorous are often attached to fine sediment particles that settle in reservoirs reducing nutrient loads to downstream aquatic species. Water that is released from the reservoirs during low flow conditions would have a beneficial effect by diluting the low flow salt concentration in the river. The GCWA Off-channel Reservoir is not expected to create any new water quality issues. The reservoir will allow the GCWA to use supplies from existing water right permits more efficiently.

New Contracts from Existing Supplies, including Expand/Increase Current Contracts, Reallocation of Existing Supplies, CLCND West Chambers System, Brazoria County Interruptible Irrigation, the TRA to Houston Contract, the TRA to SJRA Contract, and Groundwater Reduction Plans (GRPs) are not expected to create any new water quality issues. Fully utilizing existing water supplies may amplify some existing concerns, particularly contaminant concentrations due to reduced opportunities for in-stream dilution. The continued return of flows via wastewater treatment facility discharges will provide some mitigation of that effect. Typical municipal return flows are 60 percent of the total quantity diverted for use.

The Luce Bayou Interbasin Transfer will potentially improve the quality of Lake Houston, due to the blending with water from the Trinity River. However, recent studies performed by the Luce Bayou program have not indicated that this will be the case. Transfers such as this allow an increased opportunity for invasive species migration from the source to receiving waters. Additionally, the transfer will potentially reduce flow in the Trinity River below Dayton, because the Lake Livingston water rights are not fully utilized today. The effects of this reduced flow in the Trinity are mitigated by the existence of the Wallisville Saltwater Barrier at the mouth of the river, which maintains a minimum river level for navigation and prevents the migration of brackish water upstream.

Wastewater Reuse by Houston, NHCRWA and Fort Bend MUD 25, Montgomery County MUDs 8&9, Wastewater Reuse for Industry, and reuse strategies implemented as part of a Groundwater Reduction Plan (GRP) will potentially reduce in-stream flows, thus concentrating any in-stream contaminants. However, the reuse process should remove a portion of the waste load discharged from these facilities, either through the secondary treatment process or simply by the rerouting of effluent. A concern for this strategy would be the disposal method for any liquid wastes from the secondary treatment. In the case of industrial reuse, the reverse-osmosis discharge water would be injected into the bottom of the Houston Ship Channel, into an already brackish zone. The Houston Ship Channel is dredged to a depth of 45-feet (five times the depth of Galveston Bay) with fresh water flowing to the bay at the top and salt water returning on the tides at the bottom. The reverse-osmosis discharge and resultant mixing would be in the salt water layer at the bottom of this channel, increasing the salinity in the brackish zone. Further investigation will be required to determine the full environmental impacts of the reverse osmosis discharge. This reuse is not projected to occur until a time when the overall water use of the region has increased. Wastewater return flows will increase proportionally, so that the reuse of this portion will not constitute a significant reduction below current return flows.

Infrastructure and transmission line expansions including the COH infrastructure expansion, CHCRWA, NFBWA, NHCRWA, and WHCRWA transmission lines, SJRA WRAP and Water Treatment Plant strategies for Pearland, Huntsville, Harris County MUD #50, Sealy and the Lake Livingston Water Supply and Sewer Service Company (LLWSSSC) are not expected to create any new water quality issues. The water management strategies are associated with the transmission of existing supplies to new and increased contractual demands of each wholesale water provider.

The Houston Bayous Permit has the potential to reduce instream flows. The requested diversions from the Houston Bayous Permit account for 20% to 40% of the average flow in Sims, Brays, and Buffalo bayous and 40% to 70% of the average flow in White Oak Bayou. The location of the diversion facilities will also have to be located and any wetland mitigation considered appropriately.

The Sabine to Region H Transfer has the potential to introduce Neches and Sabine River water into the Trinity, San Jacinto, San Jacinto - Brazos, and Brazos basins. This strategy therefore has the potential to result in changes in water chemistry, temperature, nutrients, organic particulates, and sediment in the Neches and Trinity basins. Instream flows in the lower Sabine River will also be reduced by the additional diversion of water from the Sabine River basin. Instream flows in portions of the Neches, Trinity, and San Jacinto Rivers will increase slightly. This strategy is included in the 2011 Plan as an alternative to off-channel reservoirs in Brazoria and Fort Bend Counties. Water transferred from the Sabine to the San Jacinto basin will be used to meet demands primarily in the Brazos and San Jacinto – Brazos basins. This may be accomplished by using the imported water in lieu of Trinity water from Lake Livingston to meet demands in Harris County. Additional infrastructure would be required to convey water from the San Jacinto basin to meet demands in the Brazos and San Jacinto – Brazos basins.

Montgomery County MUD 8/9 Brackish Water Desalination will not affect other water management strategies, only the salinity in the area of the discharge. The location of the brine disposal will have to be investigated further to determine the impacts of brine concentrate effluent on the receiving surface water or groundwater.

5.3 Evaluation of Third-Party Impacts of Reduced Levels in Water Supply Reservoirs

One of the distinguishing characteristics of Region H is the abundance of recreational opportunities that enrich the quality of life of its residents. (See *Chapter 3* for a discussion of recreational water uses.) Recreation also contributes to attracting tourists and tourist dollars to the region. Some of these recreational activities are associated with water, both freshwater and salt water, and may be sensitive to water supply. The relation to water supply translates through impacts on reservoir levels, instream flows, bay and estuary inflows, water quality, habitat and aesthetics. *Table 5-1* lists recreational activities in Region H and the ways in which those activities are sensitive to water supply.

Although the major reservoirs in Region H were built and are maintained for municipal and industrial water supply, their existence has spurred the development of recreation related economic activity around their perimeters. In addition, this recreation-oriented development expands the tax base of local jurisdictions located near the reservoirs. Other water bodies similarly provide economic opportunities in recreation support activities.

Table 5-1

Recreational Activities Associated with Water in Region H

Activity	Major Sensitivity to Supply
Boating: (Canoe/kayak, sailboats, personal watercraft, power boats)	Reservoir level Instream flow Aesthetics
Swimming	Aesthetics Water quality Reservoir level Instream flow
Fishing	Reservoir level Instream flow Bay & Estuary inflows

	Water quality Habitat
Hunting	Habitat Instream flow
Parks: (Camping, hiking, biking, horseback riding)	Aesthetics Habitat Instream flow
Nature Tourism	Reservoir level Instream flow Bay & Estuary inflows Habitat Aesthetics
Golfing	Course upkeep Aesthetics

These activities impact the economy of the region through many paths, some of which are captured under the heading of "commercial activities" in the municipal water user group (WUG) in the socioeconomic analysis of water shortages (discussed in *Chapter 4*). Examples of these would be the sale of boating equipment, pier use fees collected by a convenience store or hotel receipts. Others impacts are not accounted for among the WUGs.

The determination of a direct relationship between water management strategies and recreational opportunities and indirect economic impacts is not feasible, due to the numerous other factors that affect recreational economics (i.e., weather conditions, national economic conditions, travel restrictions, etc.). However, the collective affects of strategies on anticipated lake levels during historical meteorological conditions were analyzed and some conclusions may be inferred on the impacts to recreation and economics.

For this analysis, the TCEQ Water Availability Model was updated to include the water management strategies recommended by Region C and Region H in their 2006 Regional Water Plans. The tributaries to Galveston Bay were then modeled under four scenarios to compare the results with and without the recommended strategies. The scenarios used were Run 8 "Current Conditions" (current levels of water diversions and return flows), Run 1 (full use of water rights with current percentage of return flows), Run 3 (full use of water rights with no return flows) and a future condition (full use of water rights, new strategies in place, and full return flows except for recommended reuse strategies). The first three models used the year 2000 reservoir sedimentation conditions to represent the 2010 condition, and the fourth used the 2060 condition. The future sedimentation condition benefits downstream projects, because upper basin projects have less capacity to store available flows. In this case, Lakes Houston and Livingston may be considered downstream projects.

The results of these simulations are summarized in *Table 5-2*. Reservoir elevations, capacities and surface areas are shown in *Figure 5-1*, *Figure 5-2* and *Figure 5-3* as a reference. *Appendix 5B* contains figures graphically displaying the model outputs and the percentile comparisons. Percentile values indicate the percentage of time the result value is less than or equal to the subject value. Therefore, the maximum value is the full lake elevation, the median value is the lake level in 50% of the monthly outputs, and the minimum value is the lowest monthly elevation in the simulation. Because the yield of these water supply reservoirs is based upon full use of the stored water during the drought of record, the Run 3 minimum elevation is, by definition, the lake bottom elevation. Note that this value is greater in the 2060 conditions simulation due to the projected accumulation of sediments on the reservoir floor. Each simulation run used the same 57-year inflow data set, which includes the drought of record period.

Table 5-2

Lake Level Percentile Tables

Lake Conroe Water Surface Elevations

	Current Conditions	Yr 2010 Run 1	Yr 2010 Run 3	Yr 2060 w/ Strategies
Maximum	201.0	201.0	201.0	201.0
90th	201.0	201.0	201.0	201.0
75th	201.0	200.5	200.5	200.5
Median	200.5	198.4	198.2	198.5
25th	198.6	193.6	193.0	194.2
10th	195.3	184.2	183.1	185.9
Minimum	187.8	145.0	145.0	152.0

Lake Houston Water Surface Elevations

	Current Conditions	Yr 2010 Run 1	Yr 2010 Run 3	Yr 2060 w/ Strategies
Maximum	44.0	44.0	44.0	44.0
90th	44.0	44.0	44.0	44.0
75th	44.0	44.0	44.0	44.0
Median	44.0	44.0	44.0	44.0
25th	43.3	43.3	42.8	44.0
10th	42.0	42.0	40.4	43.8
Minimum	32.8	32.8	9.0	40.3

Lake Livingston Water Surface Elevations

	Current Conditions	Yr 2010 Run 1	Yr 2010 Run 3	Yr 2060 w/ Strategies
Maximum	131.0	131.0	131.0	131.0
90th	131.0	131.0	131.0	131.0
75th	131.0	131.0	131.0	131.0
Median	131.0	131.0	129.8	131.0
25th	130.5	130.4	124.3	129.5
10th	129.0	128.0	116.5	127.1
Minimum	125.5	114.0	60.0	120.7

As can be seen from *Table* 5-2, under current conditions Lake Conroe would have a 13.2-ft elevation variation range during the historical period, Lake Houston an 11.2-ft range and Lake Livingston a 5.5-ft range. In all cases, the lakes are essentially full more than 50% of the time. To compare the runs with and without management strategies, it is best to compare Run 1 with the Recommended Strategies simulation, because both models use expected return flows.

Figure 5-1

Lake Conroe Surface Area and Capacity (2060 Conditions)

Surface Elevation	Surface Area	Storage Volume	Percent Fill
Feet (msl)	Acres	Acre-Feet	%
201 19,360		377,560	100%
195.5 15,600		283,170	75%
188.7 12,190		188,780	50%
179.5 8,500		94,390	25%
152			Bottom

Figure 5-2

Lake Houston Surface Area and Capacity (2060 Conditions)

Surface Elevation	Surface Area	Storage Volume	Percent Fill
Feet (msl)	Acres	Acre-Feet	%
44	11,850	106,410	100%
41.5	9,250	79,810	75%
38.0	7,780	53,210	50%
33.4	5,700	26,600	25%
20			Bottom

Figure 5-3

Lake Livingston Surface Area and Capacity (2060 Conditions)

Surface Elevation	Surface Area	Storage Volume	Percent Fill
Feet (msl)	Acres	Acre-Feet	%
131 82,920		1,717,080	100%
125.4 70,600		1,287,810	75%
118.6 56,920		858,540	50%
109.8 39,510		429,270	25%
63			Bottom

For Lake Conroe, full use of water rights reduces the frequency of the lake being full from 50% to 25% of the time in every simulation. The lake level falls below the current conditions minimum elevation between 10 and 25 percent of the time. The transfer of water to Lake Houston via Luce Bayou slightly increases the levels in Lake Conroe, but otherwise the two models are about the same.

For Lake Houston, the full use of water rights does not significantly change the lake level frequencies. This is mainly due to the fact that Lake Houston is senior in priority date to Lake Conroe, and therefore the model always stores available flows in Lake Houston first, and then makes the remainder available to Lake Conroe. In actual operation, a better balance is maintained between the two, but Lake Conroe will always decline faster than Lake Houston because it is supplied from a smaller watershed. Of note in the future condition simulation is that the import of water through Lake Houston via the Luce Bayou transfer increased the frequency of the lake being full from 50% to 90% of the time.

Finally, the Lake Livingston results show how dependent the reservoir is upon return flows from upstream (Run 3 condition). Under the recommended strategies run, the results are very close to the current conditions simulation. This is because increased use in the upper Trinity Basin is off-set by increased import of out-of-basin supplies. Region H indirectly benefits from the growth of the Dallas-Fort Worth Metroplex. In the current round of planning, Region C is increasing the amount of recommended reuse, although it is not expected they will reach the full-reuse condition modeled in Run 3.

The drought of record lasted six years, and subsequent droughts have exceeded two years in duration. Looking at the simulation results in *Figures 5B-1* and *5B-5*, it can be seen that when significant declines in lake levels occur, they will not be instantaneous events, but will be a subset of the overall drought period. Anecdotally, a month with low lake levels will impact a land owner’s ability to use a dock. A year with low lake levels may impact his property rental or resale value. Similar inferences may be made as to the impacts on lake area communities and businesses.

Reduced lake levels will also impact water quality. During extreme low flow periods, reduced residence time in the reservoir will lessen the beneficial effects of sediment settling. Because the climate in this area is mild, the seasonal turn-over in lakes occurs less frequently than in colder climates. When reservoirs are drawn down, the denser lower layer of water will be tapped, which may increase the level of treatment required for use.

An option to mitigate these affects is to establish a minimum storage pool for a given reservoir, and prohibit withdrawals below that level. Because that would reduce the available storage pool for these reservoirs, and thus reduce the yield, such an imposition would constitute a taking of property. As a practical matter, the establishment of a minimum storage pool (for habitat, recreation, or other uses) would need to be off-set by the development of a new source of water supply, equal in yield to that lost from the lake. Development of this additional supply would be costly, and was not considered under this plan.

5.4 Impacts of Moving Water from Rural and Agricultural Areas

Currently, the water used in rural (livestock) and agricultural areas represent 13% of the total water used in Region H, a decline from 22% estimated in the year 2000. It is estimated that this will be reduced to 12% of the Region’s 3,525,100 acre-feet demand projected in year 2060, mainly due to the growth of municipal and industrial demands. There is a slight projected decrease in irrigation (from 450,175 acre-feet per year in 2010 to 430,930 acre-feet per year in 2060, or a net reduction of 4%). Livestock demand is constant over the planning period. Water management strategies, along with current sources of reliable water supply and interruptible supplies, are available to agricultural users throughout the planning period; therefore, the impacts on agricultural users are not directly related to moving water from these areas.

The potential impacts of moving water from rural and agricultural areas are mainly associated with socio-economic impacts to third parties. The potential impetus for moving water is expected to occur from two sources: 1) the cost of raw water may become too great for the local irrigator to afford, and he may elect to voluntarily leave the industry for economic reasons; or 2) the value of the raw water for municipal or industrial purposes may create a market for the wholesale owner to re-direct the sale of the water making it unavailable to the irrigator. In some cases, it may be feasible for a third party to pay for conservation measures and then utilize the saved water for their own needs (through re-contracting or other agreements) and allow the irrigator to remain in business; however, there are few contractual and institutional measures in effect to allow this trade-off to occur at this time. The intent of this plan is to provide water or the conservation means to meet all projected water demands throughout the planning period.