High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

Edwards Aquifer Recovery Implementation Program
September 2010

Prepared by:
Ecosystem Restoration Subcommittee

Submitted to:
Steering Committee of the Edwards Aquifer Recovery Implementation Program

Program Director Gulley and EARIP Steering Committee Members,

The Ecosystem Restoration Subcommittee was asked to revisit previous restoration and minimization reports relating to the Comal and San Marcos Ecosystems, and provide details relating to those restoration actions.

Actions were evaluated based on the following criteria:

- Feasibility of implementation of restoration/mitigation action
- Cost/benefit analysis of restoration/mitigation action
- Direct benefit resulting from the restoration/mitigation action to the endangered species

Consultation and review of the following selections and establishment as high priorioty action items was approved by consensus of the EARIP Ecosystem Restoration Subcommittee, with input and review by the United States Fish and Wildlife Service, the United State Army Corp of Engineers, Texas Parks and Wildlife Department, and other environmental organizations and interests.

The submitted report includes additional details related to the implementation and cost of the previously identified restoration and mitigation actions. Where possible, specific locations and methods for implementing the actions are identified. However, the specific details of implementing most, if not all, of the actions will require further consultation with federal and state entities. Similarly, the cost estimates established by the subcommittee are intended only to establish the scale and magnitude of cost and actual cost may vary greatly at the time of implementation. Additionally, many of the restoration actions require annual costs, which may be largely dependent on the initial success of the proposed action and are thus difficult to estimate. A very broad estimate of all the restoration packages follows in table form but does not include IMa's, snail removal, or LID incentives (estimates for these recommended actions could not be established).

	One-Time Implementation $$	Annual On-Going $$/yr
San Marcos	$5,181,000.00	$541,000.00
Comal	$2,035,000.00	$490,000.00
Total	$7,216,000.00	$1,031,000.00

Consideration should also be given to the timing and sequencing of the restoration actions as certain actions may be complimentary or may be combined to save money and reduce negative impacts to the habitats. For example, the removal of non-native vegetation in the San Marcos River may be achieved more efficiently and with less disturbance to the habitat if all identified non-native species were removed simultaneously rather than individually.

It is important to note that while the below restoration and mitigation actions were identified as the top priorities with the greatest direct benefit to the listed species, this listing and prioritization is not meant to detract from the importance of all the restoration and mitigation actions identified

in the previous reports as low or medium priority. The importance of a particular action, regardless of its assigned prioritization, may change in response to future conditions or changes to the ecosystem. Thus, all of the restoration and mitigation actions identified in the totality of all reports should be considered in the HCP or as components of adaptive management to more completely reach the goal of restoring the habitats and recovering the listed species.

Respectfully,
Nathan Pence
EARIP Ecosystem Restoration Subcommittee Chair

High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at 03/23/2010 EAHP Meeting	Adaptive Management or Restoration/ Minimization	Method of Implementation and Frequency	Estimated Cost (Most effective figure and method need to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
San Marcos River	Protection of Texas wild-rice (Zizania texana) Access and Exclusion Zones, Floating Vegetation Removal, and Sedimentation Removal	Currently, recreational access is not controlled and Texas wild-rice stands are trampled and uprooted during access in shallow areas of the river	X	Restoration and Minimization	Permanent access should be located at dog beach, Lion's Club Tube Rental, Bicentennial Park, Wildlife Annex, and potentially other areas Areas between access points should be planted with vegetation that discourages streamside access (i e prickly pear, blackberry brambles) Additionally, instream exclusion zones should be established, perhaps through the State Scientific Area designation Kiosks showing access points, exclusion zones, and associated educational components should be installed at key locations	**One-Time Implementation Cost:** $375,000 5 sites x $75,000/site = $375,000 Includes limited walkways and stairs, bank stabilization, and signage Additional costs would be an extra $50,000 for educational signage and exclusion zones for Texas wild-rice **Long-Term Annual Cost:** $20,000/yr	Reduces stress and mortality to Texas wild-rice	Increase in impervious cover and reduced recreational access	State Scientific Area Designation is dependent upon approval from TPWD Commission Stakeholder involvement is crucial US Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project For success, enforcement is essential
		Floating vegetation causes direct mortality of Texas wild-rice by contributing to low light levels, smothering plant stands, and inhibiting flowering	X		Floating vegetation mats could be either pushed downstream out of listed species critical habitat or physically removed from the system Mats should be pushed or removed two times a week during the recreation season and monthly during off-season	**One-Time Implementation Cost:** $80,000 Pushing plants downstream currently costs the City of San Marcos $20,000 per year for 1/4 mile of cleared river Pushing mats from Spring Lake Dam downstream to IH 35, approximately 1 mile, makes out estimated project cost $80,000 per year Removing mats would likely increase costs by at least four times the amount **Long-Term Annual Cost:** $80,000/yr	Reduces mortality to Texas wild-rice and increases sexual reproductive success	Pushing vegetation downstream crowds mats to downstream locations Removal causes loss of aquatic life Potential trampling of aquatic plants and associated turbidity	Removal of floating debris over Texas wild-rice stands must have an approved protocol and be accomplished with permission of USFWS and TPWD
		Deposition of sediments on or around Texas wild-rice stands causes direct mortality by smothering or burying stands Targeted areas should include Upper (upstream of University Drive) and Lower Sewell Park, at and downstream of the confluence with Purgatory Creek, the Hopkins Bridge area, and upstream of IH 35	X	Restoration and Maintenance	Sediment may be removed by physical or mechanical methods An underwater vacuum is one possible mechanical method Any non-native vegetation that has established on these sediments should also be removed and Texas wild-rice established	**One-Time Implementation Cost:** $500,000 Based on cost of Crypto removal and native reestablishment in the San Marcos River in 2008, the projected cost is $500,000 per mile of river restored Thus, the estimated cost for our target areas is estimated to cost $500,000 **Long-Term Annual Cost:** Annual costs will be dependent upon sedimentation patterns Estimated recurrence interval is 5-10 years, but is heavily dependent on timing of flood events	Reestablish Texas wild-rice habitat and stands	Disturbance to habitat and possible take of Endangered Species Temporary water quality impairments	Removal of sediment must be accomplished with a USACE 404 and TPWD sand and gravel permit U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project Sediment removal may be combined with non-native vegetation removal to save money and reduce impact to habitat
San Marcos River	Prohibition of hazardous materials routes that cross the River, springs, or associated direct tributaries	Roads that cross the San Marcos River are not identified hazardous materials routes, but hazardous materials are allowed to cross A spill could be catastrophic depending on location	X	Restoration and Maintenance	Work with TXDot to establish prohibited routes Would require signage and legislation	**One-Time Implementation Cost:** $10,000 Cost would include signage and possible costs incurred in the legal process **Long-Term Annual Cost:** $0 Minimal, if any	Prevent extinction of species and/or possible damage to habitat caused by a catastrophic spill	Could cause inconvenience through lost direct routes	Work with TXDoT, Hays County, City of San Marcos, and state agencies to establish restricted zones, costs to install signage and designate alternative routes
San Marcos River	Stop or limit introductions of non-native species by aquarium "dumps"	Citizens often dump their entire aquarium into the river when they no longer can keep the aquarium, thus introducing non-native species to the ecosystem		Restoration and Maintenance	This action will be maximized through education (signage and brochures) and offering alternatives to citizens and students wanting to get rid of unwanted aquatic pets The EAHP should consider partnering with the River Systems Institute, Texas State University and local citizen groups to help distribute educational materials Partnerships with the school districts should also be considered Signage should also be provided to local pet shops and bait shops	**One-Time Implementation Cost:** $20,000 Costs in the first year for design of the campaign and printing of materials With yearly costs for additional printing **Long-Term Annual Cost:** $5,000/yr For additional signage and continued education efforts	Reduce competion of non-natives on the listed species and reduce the introduction of "new" non-native species	None	Enforcement and education are key elements One potential campaign and marketing resource could be Habitattitude (existing campaign by USFWS and NOAA)
San Marcos River	Stop or limit introductions of non-native species by the use of non-native bait species	The use of non-native species as bait can result in the introduction of "new" non-natives and potential new aquatic diseases		Restoration and Maintenance	Establish local ordinance prohibiting the use of non-native bait species in the San Marcos Springs ecosystem This action will be maximized through education (signage and brochures) and through the identification of native bait choices for citizens The EAHP should consider partnering with the River Systems Institute, Texas State University and local citizen groups to help distribute educational materials Partnerships with the school districts should also be considered Signage should also be provided to local pet shops and bait shops	**One-Time Implementation Cost:** $20,000 Costs in the first year for design of the campaign and printing of materials With yearly costs for additional printing **Long-Term Annual Cost:** $5,000/yr For additional signage and continued education efforts	Reduce competion of non-natives on the listed species and reduce the introduction of "new" non-native species	Loss of revenue to bait shops and loss of bait choices for anglers	Enforcement and education are key elements One potential campaign and marketing resource could be Habitattitude (existing campaign by USFWS and NOAA)
San Marcos River	Include private landowners (riverside and tributary) in riparian restoration	On private property, citizens often groom a yard right to the waters edge, reducing the natural ability of a riparian zone to filter runoff		Restoration and Maintenance	As plans take shape for the reestablishment of the riparian zone, public stakeholder meetings should be held and landowners should be asked to participate in the plan Reimbursement for the price of native plants should be provided to private landowners by the EAHP A program should be developed including criteria to qualify and preferred natives to replant	**One-Time Implementation Cost:** $10,000 Costs in the first year to reimburse landowners for native plants and to market the program to landowners Funding for following years is dependant on participation and success of the program **Long-Term Annual Cost:** $5,000/yr Costs will decrease after the first few years as vegetation is established	Improved water quality through the natural ability of a properly functioning riparian zone	Temporarily increased turbidity during transplant process	There are several private residents and one commercial business on the San Marcos River that are between IH35 and Spring Lake Should also focus on tributaries Sessoms, Sink, Purgatory, and Willow creeks
San Marcos River	Restoration of riparian zone with native vegetation (public lands)	On public property (e g parks and golf courses), citizens often groom property right to the waters edge, reducing the natural ability of a riparian zone to filter runoff Other concerns include trampled banks that increase erosion and the establishment of non-native vegetation		Restoration and Maintenance	As plans take shape for the reestablishment of the riparian zone, public citizens should be asked to participate in the plan Reimbursement for the price of native plants should be provided to public citizens by the EAHP A program should be developed including criteria to qualify and preferred natives to replant	**One-Time Implementation Cost:** $100,000 Costs in the first year to reimburse for native plants and to market the program Funding for following years are dependant on participation and success of the program **Long-Term Annual Cost:** $20,000/yr Costs will decrease after the first few years as vegetation is established	Improved water quality through the natural ability of a properly functioning riparian zone	Temporarily increased turbidity during transplant process	Establishment and width determination of buffer zone along riverside should be based upon best available science and should consider desired recreational access (see previous restoration action item involving Texas wild-rice and recreational access) U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project around Spring Lake area

High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at BIA/ESPB EARIP Meeting	Adaptive Management or Restoration/ Mitigation	Method of Implementation and Frequency	Estimated Cost Must give at least $5 figure and method used to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
San Marcos River	Control of harmful non-natives: domestic waterfowl, tilapia (*Oreochromis aureus*), nutria (*Myocastor coypus*), armored catfish (family Loricariidae, *Hypostomus* spp. and *Pterygoplichthys* spp.), ramshorn (*Marisa cornuarietis*), *Melanoides tuberculatus*, hydrilla (*Hydrilla verticillata*), hygrophila (*Hygrophila polysperma*), elephant ears (*Colocasia esculenta*) and water hyacinth (*Eichhornia crassipes*)	Domestic Waterfowl are known to feed directly on Texas wildrice and the seedheads, which effect population size, reproductive success, and genetic variability	X	Restoration and Minimization	Selective netting and give aways to land owners, once a year after Easter Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $20,000 The cost is largely labor associated with trapping the waterfowl and an educational campaign Estimate per year are thought to be around $10,000 - $20,000 per year Long-Term Annual Cost: $10,000/yr	Reduces the loss of Texas wildrice stands and seedbank	Public acceptance	City code should prohibit the feeding of wildlife i e The Rivet Pub and Grill sells duck food
		Tilapia are detrimental to the habitat of all associated endangered species		Adaptive Management	Tilapia are a tropical species that will congregate in warmer near spring openings and other warm water sources When the species congregate this creates the opportunity to use seines, gill nets, cast nets, or other methods to remove large quantities with minimal impact to the habitat Artificial heating could be one method used to congregate fish in areas away from springs and endangered species to minimize the impacts from collection efforts Initial efforts in year one should be intense and take place during the winters first freeze, with continued control every winter Numerous removals during each winter would be most productive Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $10,000 State and Federal agencies or Universities should be involved and would reduce the labor cost Equipment costs are estimated near $10,000 for nets and other misc gear Artificial heating is very expensive If heaters are used the price would greatly increase dependant on the size of heaters and water volume manipulated Long-Term Annual Cost: $10,000/yr	Removal primarily benefits the fountain darter Non-native species compete with native species for resources and alter habitat among other issues Specifically, tilapia destroy vegetation by making bare ground nests During times of low flow and drought this could further reduce already limited habitat for the fountain darter	Collection efforts may impact fountain darters or their habitat If electroshocking is used it is detrimental to the Fountain Darter and other species	
		Human feed directly on Texas wildrice and the seedheads, which effect population size, reproductive success, and genetic variability	X	Restoration and Minimization	Texas Wildlife Services has an acceptance program to assist with control of nuisance nutria That is done once a year during the winter months Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $1,000 Minimal Cost for bait and poison Long-Term Annual Cost: $1,000/yr	Reduces the loss of Texas wildrice stands and seedbank	Public acceptance and secondary poison	The City of New Braunfels has had a successful program implemented since 2007
		Armored catfish control - Numbers of these non-natives are growing and are detrimental to the habitat of all associated endangered species Armored catfish are herbivores and burrow into the sediment of banks and lake bottom	X	Restoration and Minimization	Armored catfish are a tropical species that will congregate in warmer near spring openings and other warm water sources When the species congregate this creates the opportunity to use seines, gill nets, cast nets, or other methods to remove large quantities with minimal impact to the habitat Initial efforts in year one should be intense and take place during the winters first freeze, with continued control every winter Numerous removals during each winter would be most productive Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $10,000 State and federal agencies or universities should be involved and would reduce the labor cost Equipment costs are estimated near $10,000 for nets and other misc gear Long-Term Annual Cost: $10,000/yr	Fountain darters is main beneficiary Non native species compete with native species for resources and alter habitat among other issues Specifically, armored catfishes create large burrows causing the loss of vegetation, destabilizing banks, and other impacts During times of low flow and drought this could further reduce already limited habitat for the fountain darter	Collection efforts may impact fountain darters or habitat	Armored Catfish are also known to eat detritus and periphyton
		The ramshorn snail during low flow is a threat to vegetation communities and the Melanoides snail is the intermediate host for the gill parasite		Adaptive Management	Physical removal by dredge or hand Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: Cost will be based upon method of removal EARIP pilot study may help refine estimated cost Long-Term Annual Cost: Annual cost will be based upon method of removal EARIP pilot study may help refine estimated cost	Reduced potential infection of fountain darters by Asian trematode (*Centrocestus formosanus*) and more stable vegetative communities during drought	Habitat destruction if dredging occurs Temporarily increased turbidity during removal process Potential take of other listed species during removal process	Pilot study is currently being funded by the EARIP
		Hydrilla is highly invasive and covers a large percentage of river bottom, thus crowding out preferred darter habitat and occupying potential Texas wildrice habitat	X	Restoration and Minimization	Hydrilla may be removed by physical or mechanical means An underwater vacuum is one possible mechanical method Removed plants should be replaced with native aquatic vegetation that may include Texas wildrice where conditions are suitable Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $1,000,000 Based on cost of Crypto removal and native reestablishment in the San Marcos River in 2008, the projected cost is $500,000 per mile of river restored Based on this estimate, the removal of Hydrilla from proposed area, including Spring Lake and 2 miles of river, is estimated to cost $1,000,000 This includes sections of Spring Lake, the slough arm of Spring lake, and the San Marcos River from Spring Lake to just below IH 35 Long-Term Annual Cost: $50,000/yr	Hydrilla removal and native replacement would increase preferred darter habitat and increase potential Texas wildrice habitat	Disturbance to habitat Possible take of Endangered Species Temporary water quality impairments	To ensure success of revegetation, water flow and quality conditions should be considered, as well as areas of that stretch of river Removal of Hydrilla in its totality ensures success by limiting recolonization U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of the project Hydrilla removal may be combined with non-native vegetation removal to save money and reduce impact to habitat
		Hygrophila is a non-native species that covers a large percentage of river bottom, thus crowding out preferred darter habitat and occupying potential Texas wildrice habitat		Restoration and Minimization	Hygrophila may be removed by physical or mechanical means An underwater vacuum is one possible mechanical method Removed plants should be replaced with native aquatic vegetation that may include Texas wildrice where conditions are suitable Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $1,000,000 Based on cost of Crypto removal and native reestablishment in the San Marcos River in 2008, the projected cost is $500,000 per mile of river restored Thus our project of Spring Lake and 1 mile of river restored is estimated to cost $1,000,000 This mile of restored river would include sections of Spring Lake, the slough arm of Spring lake, and the San Marcos River from Spring Lake to just below IH 35 Long-Term Annual Cost: $50,000/yr	Hygrophila removal and native replacement may increase fountain darter and Texas wildrice habitat	Disturbance to habitat Possible take of Endangered Species Temporary water quality impairments	It may be best to obtain grants to fund a contractor to remove the initial mass of non-natives and then have a volunteer program to stay on top of the non-natives U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project Hygrophila removal may be combined with non-native vegetation removal to save money and reduce impact to habitat
		Spread of non-native Elephant ears is causing a reduction in diversity and loss of natives Elephant ears are highly invasive and can reach densities that alter the ecosystem Elephant ears also contribute to increased evapotranspiration		Restoration and Minimization	Elephant ears may be removed by physical or chemical means Removal will likely entail physical removal of the plant itself, along with herbicide treatment of remaining tubers Removed plants should be replaced immediately with native vegetation that may include Texas wildrice where conditions are suitable Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $1,000,000. Cost will be based upon method of removal Because of difficulty of removal, costs may reach $1,000,000 Long-Term Annual Cost: $50,000/yr	Open up available habitat to flowering and sexually reproducing populations of wildrice by allowing plants to occupy shallower and slower flowing water	Temporarily increased turbidity during removal	Long term O/M efforts will be necessary U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project
		Water hyacinth is a floating non-native species that causes direct mortality of Texas wildrice by contributing to low light levels, smothering plant stands, and inhibiting flowering rice habitat Without removal efforts hyacinth has the ability to completely cover Spring Lake, altering the water chemistry (e g , DO) and available light		Restoration and Minimization	Water hyacinth may be removed by physical or mechanical means (harvester) Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	One-Time Implementation Cost: $5,000 This program is currently being conducted by the San Marcos River Foundation with volunteer labor Estimated cost is for equipment to be used by SMRF for removal Long-Term Annual Cost: $5,000/yr Annual cost reflects control of successive non-natives, such as water lettuce	Control of water hyacinth has the potential to improve WQ and increase available light		If water hyacinth in Spring Lake is not removed, during water events they have the potential to smother and dislodge Texas wildrice plants in Sewell Park U S Army Corps of Engineers is currently working with the City of San Marcos to determine the feasibility of this project

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	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at 03/13/2010 EARIP Meeting	Adaptive Management or Restoration/ Minimization	Method of Implementation and Frequency	Estimated Cost Must give exact $$ figure and method used to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
San Marcos River	Create emergency plan in case of dam failure	Should a dam breach, it could result in the sudden loss of habitat for Texas Texas wild-rice and other native aquatic vegetation or could present the opportunity to increase habitat for the listed species. A plan should be in place to address each dam in the event of a breach		Adaptive Management	TCEQ, USACE, USFWS, and TPWD should be asked to provide directive. Once directive is provided stakeholder opinion should be sought out. Edits to the plan should be made based on comments. The plan should be distributed and implemented if a dam fails	**One-Time Implementation Cost: $0** No associated costs with developing the response plan, but actual repairs or replacement, if desired, will have costs associated with them **Long-Term Annual Cost: $0/yr**	Could present the opportunity to increase habitat for the listed species		If the dam is privately owned, cooperation of the land owner will be required. TCEQ must approve any dam alteration through the permitting process. USFWS is currently modeling potential habitat creation or loss due to dam alteration
San Marcos River	Establishment of aggressive and frequent water quality monitoring (surface, stormwater, and ground) that considers location, time of day, day of week, time of year, and all water quality parameters deemed significant	Efforts to monitor water quality around Spring Lake and the San Marcos River should be increased. Trends, adaptive management measures, and concerns should be identified as soon as possible		Adaptive Management	Sampling criteria should be established through a stakeholder process, including where and when samples will be taken. Parameters evaluated should be established based on need	**One-Time Implementation Cost: $20,000** Monitoring may be accomplished, to some extent, through the work of volunteer groups such as Texas Master Naturalists and the Texas Stream Team to collect water samples, but analyses will require funding. $20,000 should be given by the EARIP to an organizing agency to administer and design a WQ sampling program **Long-Term Annual Cost: $20,000/yr**	Early detection of water quality impairments that may negatively impact the listed species. Gathered data will also contribute to body of knowledge on the Edwards Aquifer system	Potential misinterpretation of data by the public	Rivers System Institute (San Marcos observation and monitoring program) has a grant to conduct water quality sampling, but specific details are not known
San Marcos River	Implementation of Best Management Practices (BMPs) to address stormwater quality runoff in and around Spring System, could include stormwater retention ponds, water quality basins, rain gardens, wetlands, and storm sewer filters	During rain events, surface runoff enters directly into spring systems and adjacent tributaries without water quality filtration or settling Water Quality concerns from direct runoff can adversely impact threatened and endangered species and their habitat		Restoration and Minimization	Determine areas of direct runoff into spring systems that could adversely impact endangered species. Areas of particular focus should be on suspected point and non-point source pollution inflow locations. Areas of concern include, but are not limited to impervious cover, golf course and industrial runoff areas. Based on the determined areas of concern, implement the BMP that best addresses that concern Monitoring could also be conducted during qualifying rain events (> 0.5") to obtain background parameters and to identify pollutants flowing into the MS4	**One-Time Implementation Cost: $1,000,000** Cost will be dependent on which and the number of BMP's are implemented. Construction of retention/settling ponds or mechanical filtration would be anticipated, establishing the high cost associated with this action Monitoring and maintenance of the BMPs is an important aspect to optimize their efficiency. An annual budget will need to be allocated for this effort **Long-Term Annual Cost: $200,000/yr**	Improved Water Quality. Difficult to quantify positive effects unless a good background data base is developed, water quality monitoring is an important aspect to this activity	Cost and public / developer perception could be a factor	Efforts should focus on anticipated 2012 TPDES/MS4 permit compliance related activities and stormwater treatment for to benefit ES and habitat Consider illicit discharge program (illegal dumping to sanitary sewer systems/MS4), Hazmat incidents (spill response & prevention), overflow/infiltration of sewer mains, construction site runoff, public education, pesticide & fertilizer application, PAH impacts and storm event data collection

High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at 9/13/2010 EARIP Meeting	Adaptive Management or Restoration/Mitigation Identification	Method of Implementation and Frequency	Estimated Cost Must give exact $$ figure and method used to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
Comal River	Control of harmful non-natives: tilapia (*Oreochromis aureus*), armored catfish (family Loricariidae, *Hypostomus spp* and *Pterygoplichthys spp*), ramshorn (*Marisa cornuarietus*) and *Melanoides tuberculatus*	Control of Tilapia - Numbers of these non-natives are growing and are detrimental to the habitat of all associated endangered species	X	Restoration and Minimization	Tilapia are a tropical species that will congregate in winter near spring openings and other warm water sources When the species congregate that creates the opportunity to use seines, gill nets, cast nets, or other methods to remove large quantities with minimal impact to the habitat Artificial heating could be one method used to congregate fish in areas away from springs and endangered species to minimize the impacts from collection efforts Initial efforts in year one should be intense and take place during the winters first freeze, with continued control every winter Numerous removals during each winter would be most productive Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	**One-Time Implementation Cost: $10,000** State and Federal agencies or Universities should be involved and would reduce the labor cost Equipment costs are estimated near $10,000 for nets and other misc gear Artificial heating is very expensive If heaters are used the price would greatly increase dependant on the size of heaters and water volume manipulated **Long-Term Annual Cost: $10,000/yr**	Fountain darter mainly Non-native species compete with native species for resources and alter habitat among other issues Specifically, tilapia destroy vegetation by making bare groundments During times of low flow and drought this could further reduce already limited habitat for the fountain darter	Collection efforts may impact fountain darters or habitat If electroshocking is used it is detrimental to the fountain darter and other species	Possible locations for artificial heating could include backwaters near the golf course, Bleeders creek dough, and other back water areas This method has not been tested or proven effective
		Armored catfish control - Numbers of these non-natives are growing and are detrimental to the habitat of all associated endangered species Armored catfish are herbivores and burrow into the sediment of banks and lake bottom	X	Restoration and Minimization	Armored catfish are a tropical species that will congregate in winter near spring openings and other warm water sources When the species congregate that creates the opportunity to use seines, gill nets, cast nets, or other methods to remove large quantities with minimal impact to the habitat Artificial heating could be one method used to congregate fish in areas away from springs and endangered species to minimize the impacts from collection efforts Initial efforts in year one should be intense and take place during the winters first freeze, with continued control every winter Numerous removals during each winter would be most productive Control of non-natives will require annual efforts and non-natives should be disposed of out of the flood plain	**One-Time Implementation Cost: $10,000** State and Federal agencies or Universities should be involved and would reduce the labor cost Equipment costs are estimated near $10,000 for nets and other misc gear Artificial heating is very expensive If heaters are used the price would greatly increase dependant on the size of heaters and water volume manipulated **Long-Term Annual Cost: $10,000/yr**	Fountain darter is main beneficiary Non-native species compete with native species for resources and alter habitat among other issues Specifically, armored catfisher create large burrows causing the loss of vegetation, destabilizing banks, and other impacts During times of low flow and drought this could further reduce already limited habitat for the fountain darter	Collection efforts may impact fountain darters or habitat	Possible locations for artificial heating could include backwaters near the golf course, Bleeders creek dough, and other back water areas This method has not been tested or proven effective Armored catfish are also known to eat detritus and periphyton
		The ramshorn snail during low flow is a threat to vegetation communities and the Melanoides snail is the intermediate host for the gill parasite		Adaptive Management	Physical removal by dredge or hand Control of non-natives will require annual efforts and non-natives should be disposed of out of the floodplain	**One-Time Implementation Cost:** Cost will be based upon method of removal EARIP pilot study may help refine estimated cost **Long-Term Annual Cost:** Annual cost will be based upon method of removal EARIP pilot study may help refine estimated cost	Reduced potential infection of fountain darters by Asian nematode (*Centrocestus formosanus*) and more stable vegetative communities during drought	Habitat destruction if dredging occurs Temporarily increased turbidity during removal process Potential take of other listed species during removal process	Pilot study is currently being funded by the EARIP
Comal River	Optimization of Fountain Darter (*Etheostoma fonticola*) Habitat in the Old/New Channel of the Comal River	Discharge from Landa Lake to the old and new channels of the Comal River are currently set at a constant flow and never changed An established flow regime creating the maximum amount of usable habitat for the fountain darter would be beneficial, especially during low flows Change in flow volume does not relate on a 1 1 basis with usable habitat (reference Hardy models)	X	Adaptive Management	Implement a flow regime developed by a third party using the gated culverts at tee box # 2 and the LCRA weir would be necessary Coordination with Springfed pool operation should be considered	**One-Time Implementation Cost: $25,000** Cost would be associated with development of the flow regime City of New Braunfels staff could be utilized at no cost to make adjustment to valve configuration and clean intake screens It is estimated that a third party could establish the needed flow regime and criteria for $25,000 **Long-Term Annual Cost: $5,000/yr** Annual cost is for labor to maintain valve and gates	Fountain darters benefit from ensured flow, required water quality parameters, and creation of the maximum usable habitat	Some habitat may not be maintained to protect higher quality habitat	Draft MOU available, possible flow regime in the 2003 draft Mgmt Plan by Hardy et al 1999
Comal River	Establishment of riparian zones and removal of sediment in select areas to promote beetle (*Heterelmis comalensis* and *Zaitzevia comalensis*) habitat	Riparian habitat along the western shore of Landa Lake from the headwaters of Spring Run 3 downstream to the Gazebo, contains little native riparian vegetation	X	Restoration and Minimization	Method of riparian zone establishment includes the removal of all non-natives and replanting of native vegetation representing a functioning riparian zone Trees and plants with extensive root systems should be given preference to create the maximum beetle habitat Fine sediment coverings exposed roots and springs should be removed also The riparian zone should be checked several times a year for continued success and removal of reestablished non-natives It is also possible the area will need to be protected for the first year until the riparian zone becomes established	**One-Time Implementation Cost: $140,000** Project size is estimated at 10 acres Plants for establishment of riparian zone are estimated at $4,000/acre, labor for planting at $3,000/acre (includes planning), and sediment removal at $5,000/acre, plus an extra $20,000 because of hard to reach areas Total project cost of $140,000 **Long-Term Annual Cost: $15,000/yr** Costs should diminish after the first few years as vegetation is established	Comal Springs riffle beetles are thought to feed on detritus (fungus and bacteria growing on woody debris, and leaf litter) within spring-influenced riparian zones They are also known to prefer areas free of fine sediments Establishing a native riparian zone benefits the riffle beetle by increasing the amount of usable habitat and food sources Having a larger population when drought occurs likely increases the ability of the species to withstand the drought In addition, riparian restoration also benefits the system through bank stabilization and nutrient and sediment processes	Reduced recreational access and temporary turbidity	This location was chosen because the western shoreline of Spring run 3 is known to have numerous spring orifices that contain beetles and the riparian habitat is significantly degraded One species to specifically target would be elephant ears (*Xanthosoma sagittifolium* and *Colocasia esculenta*)
		Riparian habitat along the western shore of Landa Lake from the end of Spring Run 3 upstream to the Water Oriented Recreation District #1 property line, contains little native riparian vegetation	X	Restoration and Minimization					This location was chosen because the western shoreline of Landa Lake is known to have numerous spring orifices that contain beetles and the riparian habitat is significantly degraded This area was also chosen because it is one of the deeper parts of the lake (6 ft) will hold water longest during drought) and also because the population of riffle beetles found along that shoreline is thought to be the most genetically diverse found in Landa Lake One species to specifically target would be Elephant Ears (*Xanthosoma sagittifolium* and *Colocasia esculenta*)
Comal River	Prohibition of hazardous materials routes that cross the Comal River, springs, or associated direct tributaries	Roads that cross the Comal River are not identified hazardous materials routes, but hazardous materials are allowed to cross A spill could be catastrophic depending on location	X	Restoration and Minimization	Work w/ TXDot to establish prohibited routes Would require signage and legislation	**One-Time Implementation Cost: $10,000** Cost would include signage and possible costs incurred in the legal process **Long-Term Annual Cost: $0/yr**	Prevent extinction of species caused by one spill	Could cause an inconvenience through less direct routes	Work with TXDoT, Comal County, City of New Braunfels, and state agencies to establish restricted zones, cost is to install signage and designate alternative routes. City of New Braunfels has existing hazardous materials response plan

High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at 07/12/2010 EARIP Meeting	Adaptive Management or Recommendation Information	Method of Implementation and Frequency	Estimated Cost (Must give exact $$ figure and method used to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
Comal River	Include private landowners (riverside and tributary) in riparian restoration	On private property, citizens often groom a yard right to the waters edge, reducing the natural ability of a riparian zone to filter runoff		Restoration and Maintenance	As plants take shape for the reestablishment of the riparian zone, public stakeholder meetings should be held and land owners should be asked to participate in the plan Reimbursement for the price of native plants should be provided to private landowners by the EARIP A program should be developed including criteria to qualify and preferred natives to replant	**One-Time Implementation Cost:** $100,000 Cost in the first year to reimburse landowners for native plants and to market the program to land owners Funding for following years is dependant on participation and success of the program **Long-Term Annual Cost:** $10,000/yr Costs should diminish after the first few years as vegetation becomes established	Improved water quality through the natural ability of a properly functioning riparian zone	Temporarily increased turbidity during transplant process	Should focus on the private homes around Landa Lake, and property on the associated tributaries Blieders and Dry Comal creeks One species to specifically target would be elephant ears (*Xanthosoma sagittifolium* and *Colocasia esculenta*)
Comal River	Restoration of riparian zone with native vegetation (public lands)	On public property (e.g. parks and golf courses), entities often groom property right to the waters edge, reducing the natural ability of a riparian zone to filter runoff Other concerns include trampled banks that increase erosion and the establishment of non-native vegetation		Restoration and Maintenance	As plants take shape for the reestablishment of the riparian zone, public entities should be asked to participate in the plan Reimbursement for the price of native plants should be provided to public entities by the EARIP A program should be developed including criteria to qualify and preferred natives to replant	**One-Time Implementation Cost:** $500,000 Cost in the first year to reimburse for native plants and to market the program Funding for following years is dependant on participation and success of the program **Long-Term Annual Cost:** $50,000/yr Costs should diminish after the first few years as vegetation becomes established	Improved water quality through the natural ability of a properly functioning riparian zone	Temporarily increased turbidity during transplant process	Establishment and width determination of buffer zone along rivers edge should be based upon best available science and should consider denied recreational access (see previous restoration action item involving Texas wild rice and recreational access) One species to specifically target would be elephant ears (*Xanthosoma sagittifolium* and *Colocasia esculenta*) An agreement for no mow zones along San Felipe Springs was established between City of Del Rio and TPWD to protect the Devils River minnow and may serve as an example
Comal River	Stop or limit introductions of non-native species by aquarium "dumps"	Citizens often dump their entire aquarium into the river when they no longer can keep the aquarium, thus introducing non-native species to the ecosystem		Restoration and Maintenance	This action will be minimized through education (signage and brochures) and offering alternatives to citizens and students wanting to get rid of unwanted aquatic pets The EARIP should consider partnering with the River Systems Institute, Texas State University and local citizen groups to help distribute educational materials Partnerships with the school districts should also be considered Signage should also be provided to local pet shops and bait shops	**One-Time Implementation Cost:** $20,000 Costs in the first year for design of the campaign and printing of materials With yearly costs for additional printing **Long-Term Annual Cost:** $5,000/yr For additional signage and continued education efforts	Reduce competion of non-natives on the listed species and reduce the introduction of "new" non-native species	None	Enforcement and education are key elements One potential campaign and marketing resource could be Habitattitude (existing campaign by USFWS and NOAA)
Comal River	Stop or limit introductions of non-native species by the use of non-native bait species	The use of non-native species as bait can result in the introduction of "new" non-natives and potential new aquatic diseases		Restoration and Maintenance	Establish local ordinance prohibiting the use of non-native bait species in the Comal Springs ecosystem This action will be maintained through education (signage and brochures) and through the identification of native bait choices for citizens The EARIP should consider partnering with the River Systems Institute, Texas State University and local citizen groups to help distribute educational materials Partnerships with the school districts should also be considered Signage should also be provided to local pet shops and bait shops	**One-Time Implementation Cost:** $20,000 Costs in the first year for design of the campaign and printing of materials With yearly costs for additional printing **Long-Term Annual Cost:** $5,000/yr For additional signage and continued education efforts	Reduce competion of non-natives on the listed species and reduce the introduction of "new" non-native species	Loss of revenues to bait shops and fees of bait thrown for anglers	Enforcement and education are key elements One potential campaign and marketing resource could be Habitattitude (existing campaign by USFWS and NOAA)
Comal River	Implementation of Best Management Practices (BMP's) to address stormwater quality runoff in and around Landa Lake, could include stormwater retention ponds, water quality basins, rain gardens, wetlands, and storm sewer filters	During rain events, surface runoff enters directly in to Landa Lake, spring runs and adjacent tributaries without water quality filtration or settling Water Quality concerns from direct runoff can adversely impact threatened and endangered species and their habitat		Restoration and Maintenance	Determine areas of direct runoff into Landa Lake and Springruns that could adversely impact spring endangered species Areas of particular focus should be on suspected point and non-point source pollution inflow locations Areas of concern include, but are not limited to, impervious cover, golf course and industrial runoff areas Based on the determined areas of concern, implement the BMP that best addresses that concern Monitoring could also be conducted during qualifying rain events (> 0.5") to obtain background parameters and to identify pollutants flowing into the MS4	**One-Time Implementation Cost:** $1,000,000 Cost will be dependent on which and the number of BMP's are implemented Construction of retention/settling ponds or mechanical filtration would be anticipated, establishing the high cost associated with this action Monitoring and maintenance of the BMP's is an important aspect to optimize their efficiency An annual budget will need to be allocated for this effort **Long-Term Annual Cost:** $200,000/yr	Improved water quality	Hard to quantify positive effects unless a good background data base is developed, water quality monitoring is an important aspect to this activity Cost and public / developer perception could be a factor	Efforts should focus on anticipated 2012 TPDES/MS4 permit compliance related activities and stormwater treatment for to benefit ES and habitat Consider illicit discharge program (illegal dumping to sanitary sewer systems/MS4), Hazmat incidents (spill response & prevention), overflows/infiltration of sewer mains, construction site runoff, public education, pesticide & fertilizer applications, PAH impacts and storm event data collection
Comal River	Development of permanent and one-day Household Hazardous Wastes (HHW) collection programs (including fixed & drop-off) along with increasing awareness about discarding HHW	Often hazardous materials are discarded by flushing down toilets or pouring on the ground, down an abandoned well, or in a storm sewer		Restoration and Maintenance	Development of a HHW Program can be initiated through the TCEQ and/or the waste disposal division of the City State and local agencies could establish a 4 times a year program and could be a contributing activity that can be recognized in the City's anticipated MS4 compliance and Stormwater permit A consideration could be to have an environmental firm that specializes in waste disposal services such as Clean Harbors Environmental Inc or Curbside Inc	**One-Time Implementation Cost:** $150,000 The cost of the program would be associated with staffing, advertising, disposal, and law enforcement (if drugs are accepted) Collection dates and reasoning/benefits to dispose of hazardous materials properly should be advertised heavily The cost would be annual as this program would need to be conducted annually **Long-Term Annual Cost:** $150,000/yr	Improved stormwater quality, sub-surface flows to springs and effluent discharge	Quantifying the water quality improvements could be challenging, but overall, not a controversial issue Water quality monitoring is an important aspect to this activity	The City of New Braunfels does currently have a limited HHW program and could be considered as a compliance activity as part of their upcoming MS4 permit issuance which is believe to occur in 2012
Comal River	Implement an aerobic and anaerobic septic system registration, evaluation, and permitting program to prevent subsurface pollutant loadings from potentially being introduced to the spring ecosystem	Malfunctioning, non-permitted/registered or poorly maintained septic systems can adversely effect water quality Some underground septic systems potentially leach nutrients (i.e. nitrates) and other constituents of concern into the springs ecosystem via groundwater transport pathways and waterways that drain into spring ecosystems		Restoration and Maintenance	Associated municipalities and entities should participate in the existing TCEQ permitting, maintenance, and construction program for on-site sewage facilities (septic systems) The regulatory body should consider a more frequent analysis of the systems treatment capacity greater than TCEQ's program requirements Another option, in conjunction with TCEQ would be to assist those affected by the new program, the City/County could mail information/registration packages to owners of land parcels that lie within 500 feet of the edge of a specified waterway	**One-Time Implementation Cost:** $10,000 Costs would be minimal to the EARIP, as users must pay the registration fee with TCEQ A cost associated with sci/formation mailings could be considered However, if a conventional system is in need of upgrading, a program rebate or financial assistance should be considered **Long-Term Annual Cost:** $10,000/yr	Improved water quality	The cost for an upgrade to a more efficient system could be a financial burden upon the homeowner Some home owners may also be unwilling to voluntarily register and participate in the program	A review of the existing systems and their current permitting status, type of system and their effluent water quality along with system condition should be performed above TCEQ's current condition
Comal River	Establish incentive program that promotes new low impact development and reduces the percentage of impervious cover	Impervious cover reduces aquifer recharge and contributes to stormwater pollution Vehicles and roadways combined represent a direct pathway for pollutants to waterways during rain events		Adaptive Management	Refer to the LID EARIP Workgroup for Implementation Strategies and BMP's The Ecosystem Restoration Subcommittee supports their conclusions and recommendations Criteria and incentives need to be established	**One-Time Implementation Cost:** ??? Cost of the program would be associated with reimbursement or credit for conversion of impervious to pervious cover and incentives for new LID development and is dependant upon the type of incentives offered **Long-Term Annual Cost:** ???	Reduction of impervious cover improves the quantity and quality of water recharging the aquifer Also improves the quality of surface water runoff and attenuates floodflows	Cost of development increases	Could target specific areas around Landa Lake or direct tributaries
Comal River	Establishment of aggressive and frequent water quality monitoring (surface, stormwater, and ground) that considers location, time of day, day of week, time of year, and all water quality parameters deemed significant	Efforts to monitor water quality around Landa Lake and the Comal River should be increased Trends, adaptive management measures, and concerns should be identified as soon as possible		Adaptive Management	Sampling criteria should be established through a stakeholder process, including where and when samples will be taken Parameters evaluated should be established based on need	**One-Time Implementation Cost:** $20,000 Monitoring may be accomplished, to some extent, through the work of volunteer groups such as Texas Master Naturalists and the Texas Stream Team to collect water samples, but analyses will require funding $20,000 should be given by the EARIP to an organizing agency to administer and design a WQ sampling program **Long-Term Annual Cost:** $20,000/yr	Early detection of water quality impairments that may negatively impact the listed species Gathered data will also contribute to body of knowledge on the Edwards Aquifer system	Potential misinterpretation of data by the public	The Clean Rivers Program is currently monitoring water quality in the ecosystem

High Priority Restoration and Mitigation Actions for the Comal and San Marcos Springs Ecosystems

	Restoration Action	Issue or Problem Addressed	Approved by Steering Committee at 9/13/2010 EARIP Meeting	Adaptive Management or Restoration/Mitigation	Method of Implementation and Frequency	Estimated Cost Must give exact $$ figure and method used to determine	Direct Benefit to Listed Species	Potential Negative Impact	Additional Comments
Require Additional Information	Control of the non-native Asian trematode (*Centrocestus formosanus*), from both Spring Systems	The gill parasite can cause stress to the fountain darter and eventually mortality, especially during low flows	X	Adaptive management	Method needs to be established, possible baffle and aeration systems installed on low water dams and water control structures	The cost is unknown. Depends on method of implementation	Reduced stress or mortality to the fountain darter	??	Two possible partial but untested control methods are physical removal of *M. tuberculatus* (by dredging) and water turbulence (dams, riffles, and air bubble) to kill drifting *C. formosanus* cercaria. These methods have not been tested or proven effective
	In-Situ Refugia at Comal	In-Situ Refugia may create temporary habitat for endangered species in their native habitat during times of low flow	X	Adaptive management	Needs more work study, Biowest is currently conducting a feasibility study		Depends on approach and BioWest determination. Presumably the fountain darter and possibly the beetles	??	This is dependant on results of the BioWest In-Situ Refugia feasibility study. Bio-West indicates in-situ refugia is only viable at flows between 130-50 cfs