TTWC - SAN MARCOS RIVER

This paper was co-presented by Dr Thomas Hardy in Trondheim, Norway on June 23, 2014, two months *before* the first public discussion in San Marcos, TX was held about the possibility of removing Cape's Dam from the San Marcos River.

Attachment P

10[th] ISE 2014, Trondheim, Norway

ASSESSING POTENTIAL REMOVAL OF TWO LOW-HEAD DAMS IN AN URBANZIED TEXAS KARST STREAM

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Low head dam modification or removal is a common rehabilitation strategy in urban streams to reestablish the natural dynamic state of a stream channel and corresponding ecological processes. However, it is important to evaluate how local environmental conditions will respond to low head dam modification or removal and assess the corresponding effects it will have on the aquatic community. We modeled two different scenarios of two low head dams in the upper San Marcos River (Texas); modification representing half the existing height (i.e., partial removal) and complete removal to predict changes in available habitat for the fish and macrophyte communities. Additional topography data was collected in conjunction with sediment type and distribution data to refine existing calibrations for the two-dimensional hydrodynamic hydrodynamic model of the river. Standard engineering practices were used to calibrate the hydraulic model until agreement between predicted and observed water surface elevation profiles were achieved for existing dam conditions. Water surface profiles for partial and complete dam removal scenarios were derived from standard step-backwater modeling using surveyed channel properties. Simulation results were integrated with biological response functions to assess the ecological implications for each scenario. The resulting assessment suggests partial or complete removal of the two low head dams would be conducive to expansion of aquatic vegetation growth and would likely extend the distribution of species of special concern in the upper San Marcos River.

1 INTRODUCTION

Rehabilitation efforts in urban streams often include approaches to improve hydromorphology (Hughes *et al.* [1]) with dam removal or modification suggested as a potential mechanism for restoring the natural flow regime and channel morphology (Doyle *et al.* [2]). Channel adjustments post dam removal usually consist of a suite of alterations in the width, depth, and alignment of the channel as the system reestablishes equilibrium (Pizzuto [3]) and generally results in increased bed slope reducing water depths and increasing current velocities (Hart [4]). Dam removal reestablishes normal fluctuations and magnitudes of flow within streams, restoring many ecological processes and improving habitat for native biotic communities (Bednarek [5]). However, the rate, magnitude, duration, and spatial extent of such hydromorpohology changes vary and depend on various characteristics of the dam, river, and watershed (Poff and Hart [6]). Consequently, predicting hydromorphology adjustments and corresponding habitat changes associated with dam removal can be difficult (Doyle *et al.* [2]). Hydraulic modeling is a useful tool for predicting channel and instream changes associated with dam removal or modification, which can then be applied in assessing potential effects on the native biotic communities.

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The Edwards Plateau region in Texas contains one of the largest karst aquifers (i.e., Edwards Aquifer) in North America, serving as a major water source for an increasing urban population and several streams supporting distinct biological communities (Loáiciga [7]; Maxwell [8]). Within the last several decades, urbanization effects among Edwards Plateau streams have become a growing concern (Sung and Li [9]) with alterations to hydromorphology associated with impoundments among listed concerns. Several low head dams were constructed in Edwards Plateau streams during the early 1900s for water supply or industrial purposes. Although historically beneficial, many of these low head dams are now physically deteriorated or no longer serve the purpose for which they were constructed. Streams supplied by the Edwards Aquifer provide habitat for 90 endemic aquatic species (Maxwell [8]). Among endemic species, many are listed as imperiled with range reduction from low head dams and other urban influences among factors attributed to their decline (Bowles and Arsuffi [10]). Aging of low head dams, coupled with increase awareness of negative urbanization effects, poses dam removal or modification as a possible rehabilitation strategy for Edwards Plateau streams.

The purpose of this study was to predict instream changes associated with two low head dam modifications or removals in an Edwards Plateau stream using adaptive hydraulics modeling (ADH). The upper San Marcos River (Texas) contains two low head dams (Capes Dam and Cummings dam) and supports several endemic and listed taxa including, five federally listed species. Constructed in the early 1900's for milling of agricultural products and irrigation, Capes Dam and Cummings Dam are functionally obsolete and are currently in consideration for modification or removal. Previous assessments of the upper San Marcos suggest loss of endemic taxa between Capes Dam and Cummings dam, attributed to loss of lotic habitat within the reach (Poole and Bowles [11]; Behen [12]). Specific objectives of this study were to 1) model changes in available habitat with the partial and full removal of Capes Dam and Cummings Dam and 2) estimate changes to available habitat for endemic taxa by assessing changes in weighted useable area (WUA) for two listed species, the endangered Texas wild rice (*Zizania texana*) and the threatened fountain darter (*Etheostoma fonticola*). Understanding habitat changes associated with dam modification or removal would be useful when developing management strategies for the upper San Marcos River and other Edwards Plateau streams contending with urbanization stressors.

2 Methods

2.1 Study Area

The study area of upper San Marcos River includes the reach between the confluence with the Blanco River and Cumming's Dam and upstream into the San Marcos River to the point upstream of backwater influence from Capes Dam (i.e., approximately 6.5 rkm).

Figure 1. Study area map

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2.2 Field data collection for channel topography and substrate

Topography (i.e., elevation), substrate, vegetation, and surface water elevation data were collected from September 2009 – April 2010. Standard survey equipment and GPS Trimble XH units were used to measure topography within the wetted portion of the stream using a systematic irregular sampling strategy that targets capturing all available heterogeneity within the stream. Latitude (x), longitude (y), depth, and substrate type were recorded in Trimble dictionaries for each point surveyed. Over 61,000 data points were surveyed within the study reach for use in development of the hydrodynamic computational mesh. Vegetation within the stream was delineated with polygons with corresponding percentages of each vegetation or substrate type recorded for each polygon. Discharge and water surface elevation (WSE) longitudinal profiles were recorded each day during field measurements of channel topography.

2.3 Substrate determination in greater depths

The section of San Marcos River between the confluence with the Blanco River and Cumming's Dam consists of depths greater than 3 meters and the substrate is not visible from the surface. Therefore, river bed substrate samples in this reach were collected with an Eckman dredge. Sediment collection transects were spaced approximately 200m apart with three to five samples taken per transect. Sediment sample transects started at Cumming's Dam and continued upstream 200m past the confluence of the San Marcos and Blanco rivers. The samples were labeled and placed in plastic bags for transport for laboratory analysis.

2.4 Model calibration and simulation

Initial water surface elevations under existing conditions were obtained from the calibrated two-dimensional hydrodynamic models developed at Texas State University (Hardy *et al.* [13]). Additional field topography observations collected by Texas State University were used to supplement existing topography data in Hardy *et al.* [13] during mesh construction. Sediment type and distribution were determined using previous field data collected by Texas State University (Hardy *et al.* [13]), supplemental substrate determinations, and sediment data from Dr. Paul Hudson from the University of Texas. The Adaptive Hydraulics (ADH) model included 15 different substrates, including areas that consisted of 100 percent silts, sands, cobbles, and gravels, and mixtures of materials such as sands and gravels, gravel-cobble, etc. Also included in the model as a separate roughness region are areas of very dense vegetation. Roughness values "Manning's n" varied from .026 to .075, the highest value used, .075, was for areas of dense vegetation.

Four different steady flows were modeled for this the study, these flows ranged from 1.28 to 8.5 cms are shown in Table 1. Hydraulic model calibrations followed standard engineering practice by changing model parameters such as roughness and viscosity until agreement between predicted and observed water surface elevation profiles were achieved under existing dam conditions. For the half-height dam scenario, the dam height was simply reduced to half its current elevation. For the no-dam scenario, the dam was effectively removed to approximate the bed elevation above and below the dam based on measured elevation data. Dam height elevations used in this modeling effort are shown in Table 2. Partial and complete dam removal scenario water surface profiles were derived from standard step-backwater modeling using surveyed channel properties. Mapping of the raw data to a defined computational mesh was accomplished using triangular irregular networks to derive a mesh of approximately 14.37 m^2 resolution. Solution files for each dam and flow scenario, comprised of x, y, depth, velocity, water surface elevation, bed elevation, and cell area were exported and vegetation polygons were spatially joined with the hydrodynamic modeling grids to assign roughness values and vegetation class attributes for habitat modeling of darters.

Table 1. Modeled discharges and percent time exceeded for the San Marcos River, Texas.

Discharge cms	Percentage of time flow equaled or exceed * (1995-2011)
1.28	Never Observed
2.83	90
4.9	50
8.5	10

*Flows Measured at USGS Gage 08170500 San Marcos River at San Marcos, Texas

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Table 2. Capes Dam (right and left side) and Cumming's Dam elevation (m) at full dam height, half dam height, and full dam removal (no dam).

	Full Dam Height	Half Dam Height	No Dam
Capes Dam Right Side	167.9 m 550.8 ft	167.38 m 549.1 ft	166.87 m 547.5 ft
Capes Dam Left Side	168.22 m 551.9 ft	167.53 m 549.6 ft	166.84 m 547.4 ft
Cummings dam	163.32 m 535.8 ft	161.52 m 529.9 ft	159.71 m 524.0 ft

Table 2 is the same data used for Cape's Dam as the Jan 17, 2012 report prepared for US Fish & Wildlife (see Attachment K, Page 5, Table 3) which produced different results than presented in this report, Attachment P, from 2014.

2.5 Physical Habitat Quantity and Quality

Texas Wild Rice

Simulation results from the Surface Water Modeling Software (SMS) solution files were exported into Microsoft Excel to generate Texas wild rice component habitat suitability index (HSI) values for depth and velocity at each computational element based on the component habitat suitability criteria (HSC) values for depth and current velocity. Texas wild rice HSC for depth and current velocity suitability adapted from Saunders *et al.* [14] were used to generate predicted Texas wild rice weighted useable area (WUA) for each modeled discharge and dam scenario. Component HSI values ranged from 0.0 to 1.0, with a value of 0.0 indicating no suitability whereas a 1.0 indicates 'optimal' conditions. The combined suitability for Texas wild rice was derived as the geometric mean of the component suitabilities for depth and current velocity as follows:

$$\text{TWR Combined Suitability} = (\text{TWRdS} * \text{TWRcvS})^{1/2} \quad (1)$$

Where TWRdS is the depth suitability and TWRcvS is the current velocity suitability. Weighted useable area WUA was expressed as the percent of the total surface area for each discharge.

Fountain Darter

Simulation results from the SMS solution files combined with the vegetation and roughness files were exported into Microsoft Excel to generate fountain darter component HSI values for depth, current velocity, and substrate/vegetation at each computational cell based on the component HSC values for depth, current velocity, and substrate/vegetation. Fountain darter HSC for depth, velocity, and vegetation/substrate adapted from Saunders *et al.* [14] and data provided by BIO-WEST, Inc. [15, 16] were used to generate predicted fountain darter WUA for each modeled discharge and dam scenario. Component HSI values ranged from 0.0 to 1.0, with a value of 0.0 indicating no suitability whereas a 1.0 indicates 'optimal' conditions. The combined suitability for fountain darters was derived as the geometric mean of the component suitability's for depth, current velocity and substrate/vegetation as follows:

$$\text{Combined Suitability} = (\text{FDdS} * \text{FDcvS} * \text{FDsubS})^{1/3} \quad (2)$$

Where FDdS is the depth suitability, FDcvS is the current velocity suitability, and FDsubS is the substrate/vegetation type suitability. Weighted useable area was expressed as the percent of the total surface area for each discharge.

3 RESULTS

3.1 San Marcos Physical Habitat Modeling

A total of 61,774 topography and substrate points were collected within the study area (September 2009 – January 2010). Additional points from Hays County, Texas elevation contour maps were incorporated to extend elevation outside the river's edge. These data were used to generate the hydraulic and habitat computational meshes containing 11,955 cells of approximately 14.37 square meters/cell.

3.2 Simulated Physical Habitat

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Compare this report, dated June 23, 2014 (Attachment P, page 5) with Hardy's report dated Jan 17, 2012 (Attachment K, page 8)

In both reports Hardy utilizes the same dam height scenarios (full, half, none) and same water volumes (45, 100, 175, and 300cfs) yet derives different **Depths** and **Velocities.**

Compare this page (Attachment P, page 5, Table 3) - to Attachment K, page 8, Table 6 for **Depth**
Compare this page (Attachment P, page 5, Table 4) - to Attachment K, page 8, Table 7 for **Velocity**

Table 3. Range (mean) of modeled depths (m) within the study area of the San Marcos River at various discharges for three dam scenarios including full dam height, half dam height, and no dam.

Discharge (cms)	Full Dam Height (ft)	Half Dam Height (ft)	No Dam (ft)
1.28 45 CFS	0 - 4.82 (1.79) (5.87)	0 - 3.92 (1.16) (3.80)	0 - 3.77 (1.01) (3.31)
2.83 100 CFS	0 - 4.91 (1.93) (6.33)	0 - 4.11 (1.33) (4.36)	0 - 4.03 (1.18) (3.87)
4.90 175 CFS	0 - 5.00 (2.08) (6.82)	0 - 4.34 (1.50) (4.92)	0 - 4.28 (1.36) (4.46)
8.50 300 CFS	0 - 5.14 (2.28) (7.48)	0 - 4.60 (1.74) (5.70)	0 - 4.54 (1.60) (5.24)

Table 4. Range (mean) of modeled current velocities (m/s) within the study area of the San Marcos River at various discharges for three dam scenarios including full dam height, half dam height, and no dam.

Discharge (cms)	Full Dam Height (f/s)	Half Dam Height (f/s)	No Dam (f/s)
1.28 45 CFS	0 - 0.21 (0.04) (0.13)	0 - 0.21 (0.05) (0.16)	0 - 0.22 (0.05) (0.16)
2.83 100 CFS	0 - 0.27 (0.07) (0.22)	0 - 0.29 (0.10) (0.32)	0 - 0.30 (0.10) (0.32)
4.90 175 CFS	0 - 0.37 (0.11) (0.36)	0 - 0.39 (0.13) (0.42)	0 - 0.40 (0.13) (0.42)
8.50 300 CFS	0 - 0.59 (0.17) (0.55)	0 - 0.50 (0.20) (0.65)	0 - 0.62 (0.21) (0.68)

3.3 Simulated TWR WUA

The results for simulated TWR WUA at a discharge of 1.28, 2.83, 4.90, and 8.50 cms for each dam scenario are illustrated in Figure 2. Total predicted TWR WUA ranged from 63,847 m^2 at 8.50 cms (full dam height) to 98,732 m^2 at 2.83 cms (no dam). Overall, the simulated removal of Capes Dam and Cummings Dam provided greater available areas of TWR habitat. This is attributed to the increase in depth availability of areas less than 1 meter deep with the removal of Cumming's Dam (TWR suitability reduces greatly for depths >1m). Figure 3 provides a comparison of the combined suitability based on depth and velocity HSC for TWR at 4.90 cms for a section of the study area for three dam scenarios (0.0 low suitability – 1.0 high suitability).

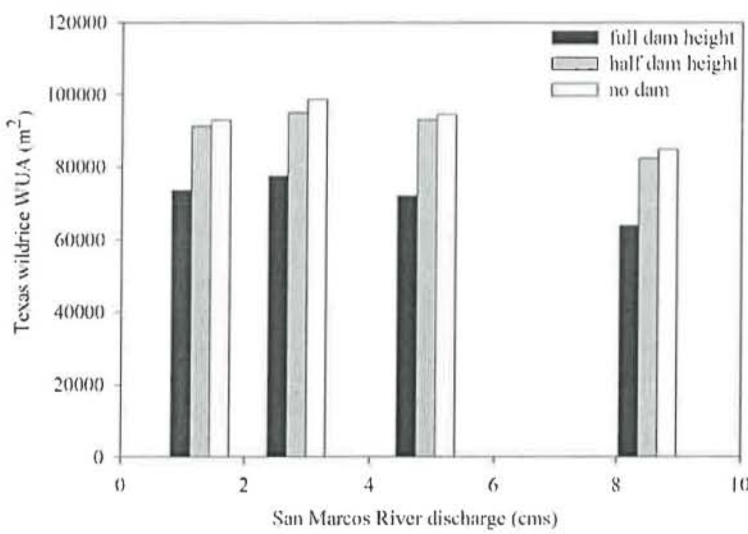

Figure 2. Predicted TWR WUA (m^2) within the study area of the San Marcos River at discharges of 1.28, 2.83, 4.90, and 8.50 cms for three dam scenarios including full dam height (black bars), half dam height (gray bars), and no dam (white bars).

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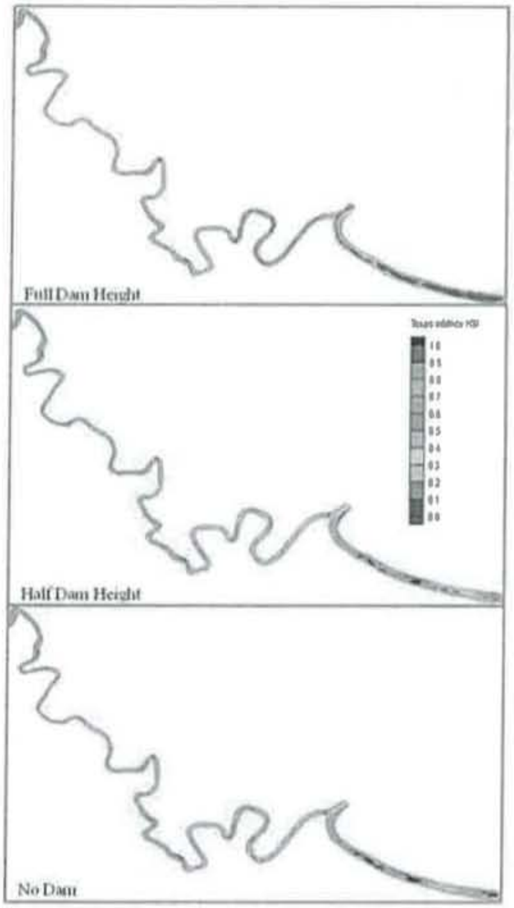

Figure 3. Combined suitability for TWR physical habitat at 4.90 cms for Cumming's Dam scenarios including full dam height, half dam height, and no dam within the study area of the San Marcos River.

The percent of TWR WUA as a function of stream surface area within the study area of the upper San Marcos River decreased with increasing discharge. The scenario of completely removing Capes dam and Cummings dam predicted the highest percent use of stream area for TWR WUA among all discharge rates (65.51% at 1.28 cms – 52.05% at 8.50 cms) whereas full dam height scenario predicted the lowest (44.32% at 1.28 cms – 36.53% at 8.50 cms, Figure 4).

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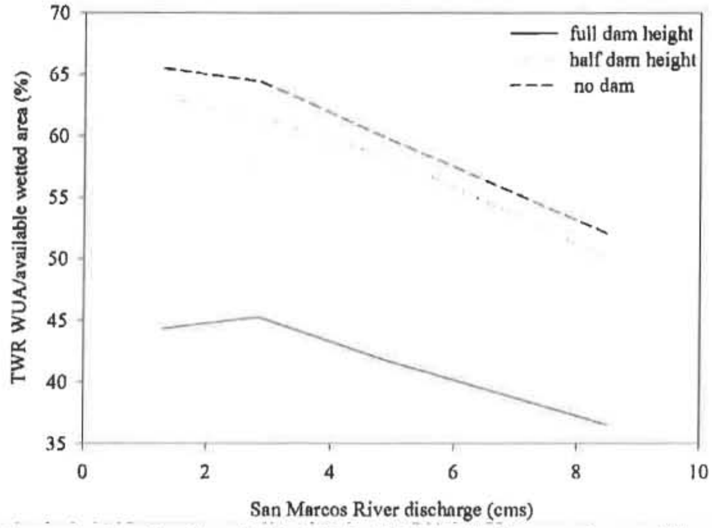
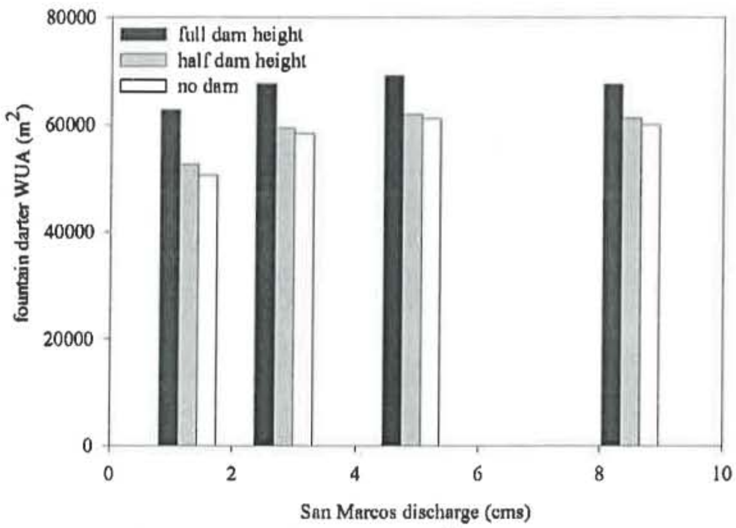


Figure 4. Predicted available TWR WUA/available wetted area (%) within the study area of the San Marcos River at discharges of 1.28, 2.83, 4.90, and 8.50 cms for three dam scenarios including full dam height (solid line), half dam height (dotted line), and no dam (dashed line).

3.4 Simulated Fountain Darter Physical Habitat

Totals for predicted fountain darter WUA are provided illustrated in Figure 5. Fountain darter WUA in the study area ranged from 50,502 m^2 at 1.28 cms (no dam) to 69,141 m^2 at 4.90 cms (full dam height). Figure 6 provides a comparison of the combined suitability for fountain darter at 4.90 cms for a section of the study area for three dam scenarios.



4th flow rate of 300 cfs is included in this chart, but it is omitted from the CoSM's 2015 reports, even though all 4 flow rates are specified in Contract with city.

Figure 5. Predicted fountain darter WUA (m^2) within the study area of the San Marcos River at discharges of 1.28, 2.83, 4.90, and 8.50 cms for three dam scenarios including full dam height (black bars), half dam height (gray bars), and no dam (white bars).

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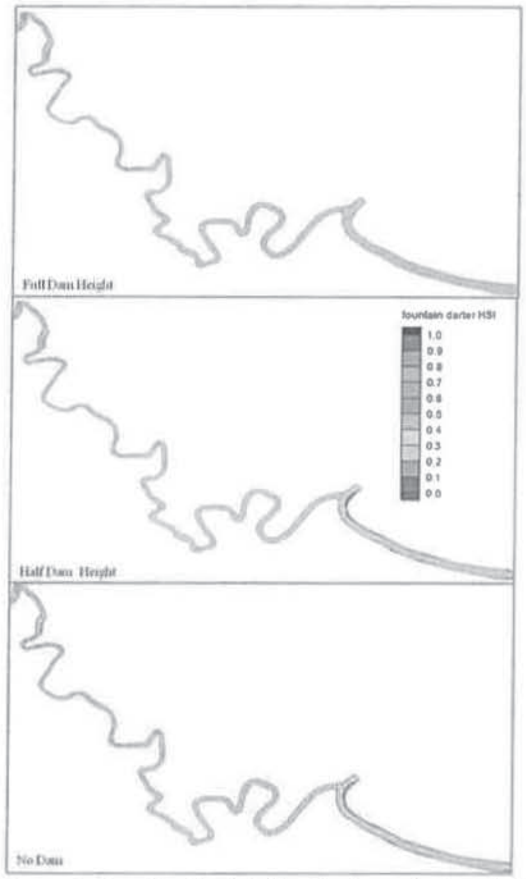

Figure 6. Combined suitability for fountain darter habitat at 4.90 cms for three dam scenarios including full dam height, half dam height, and no dam within the study area of the San Marcos River.

Fountain darter WUA as a percent of total stream area increased between 1.28 cms and 4.90 cms but decreased at 8.50 cms for all three dam scenarios (Figure 7). Maintaining Capes and Cumming's dam at full height predicted a higher percent of available habitat of suitable fountain darter habitat, but only slightly (40.03% at full dam height versus 38.61% at no dam at 4.90 cms).

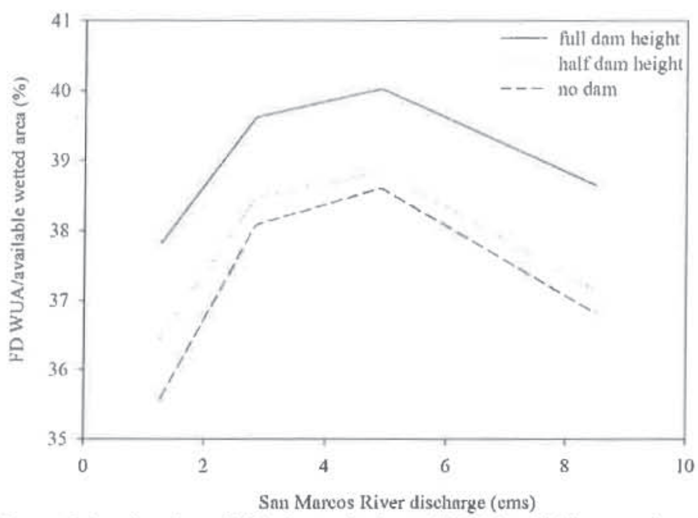

Figure 7. Predicted available fountain darter WUA/available wetted area (%) within the study area of the San Marcos River at discharges of 1.28, 2.83, 4.90, and 8.50 cms for three dam scenarios including full dam height (solid line), half dam height (dotted line), and no dam (dashed line).

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This statement "With predicted shallower water depths" is directly contradicted in many newspaper articles. Please see Jun 8, 2016 University Star article "The removal of Cape's Dam provokes disagreement" for the statement, "Hardy has assured us the river will not be shallower. It will deepen" [with dam removal.]

4.0 DISCUSSION

Use of hydraulic modeling provided insightful predictions on instream changes associated with the removal of two low head dams. Modeling results followed observations from other low head dam removals, predicting a drop in the water surface elevation, decreasing water depth and causing an increase in current velocities upstream of the dams (Doyle *et al.* [17]). Overall, water depth within the modeled reach dropped between 0.5 – 1.0m. With predicted shallower water depths and increased current velocities, run and riffle habitats would likely increase, converting this reach from a primarily lentic environment to a more lotic environment (Kanehl *et al.* [18]). Similar environmental changes in other streams following dam removal resulted in positive shifts of the biotic communities with general decreases in tolerant taxa coupled with increases in sensitive taxa (Catalano *et al.* [19]). Our modeling results suggest partial or complete removal of Capes Dam and Cummings Dam would extend suitable habitat for several endemic species and supplement current rehabilitation efforts occurring in the upper San Marcos River.

Overall, our modeling results suggest TWR habitat would substantially improve under half-height or complete removal of Capes Dam and Cummings Dam when compared to existing conditions. The incremental increase (i.e., approximately 25% more TWR WUA) in TWR habitat is primarily attributed to reduced water depths under half-height and no dam scenarios. In the lower section of the upper San Marcos River, reduced water depths would allow greater water column sunlight penetration and likely increase growth and expansion of TWR (Rybicki *et al.* [20]; Kurtz *et al.* [21]). Furthermore, increased velocity fields under half-height and no dam scenarios would likely reduce nutrient concentrations from the San Marcos Sewage treatment plant effluent released into this area plant with the removal of existing backwater affects and promote more ideal conditions for TWR (Bednarek [5]; Groeger et al. [22]).

In general, our modeling results did not suggest habitat improvement for fountain darters predicting more suitable habitat under existing conditions than dam removal scenarios. Fountain darters inhabit slow-moving (i.e., Slackwater) habitats often associated vegetation areas (Behen [12]; Phillips et al. [23]). Therefore, the predicted incremental decrease (i.e., approximately 4%) in fountain darter habitat was attributed to increased current velocities under half-height and no dam scenarios. Although incremental reductions in fountain darter habitat was predicted with dam removal, we note that our results do not incorporate expected increases in aquatic vegetation that likely will occur under half-height or no dam scenarios given that TWR was predicted to increase.

This statement contradicts all subsequent reports to the City of San Marcos, written after this date and presented to the City in 2015. The 2015 reports written by Hardy for the City of San Marcos (which contradictorily stated there would be improved habitat with Capes Dam removed) were the basis of the City Council's March 2016 vote to remove Capes Dam.

Our study presents a trade-off situation with partial or complete removal of two low head dams predicted to benefit one species while reducing habitat for another species. Modeling results suggest a notable increase in TWR habitat coupled with a small decrease in useable fountain darter habitat (4%) with dam removals. Therefore, the next step for managers and stakeholders of the San Marcos River will be to weigh the value of increasing habitat for one species while slightly reducing habitat for another species.

This report was presented in Norway **two months *prior*** to the ***first* public discussion in San Marcos** at the Parks & Recreation Board.

The Aug 2014 Parks & Rec meeting was held while there were approved funds to rebuild Cape's Dam in the CIP (Capital Improvement Projects) budget.

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