Aquatic Science Course

# Lesson Name

Teacher Page

## Salamander Threats/Solutions

***Enduring Understandings***

Research in aquatic science fields allows us to study and conserve aquatic resources and environments.

***Vocabulary***

**Anthropogenic** - Effects, processes, or materials that are derived from human activities, as opposed to those occurring in biophysical environments without human influence.

**Surrogate** - In reference to this report: *E. nana* is a similar species to *E. sosorum* but is not endangered. E. nana is used in place of *E. sosorum* in laboratory trials.

**Threatened -** Any species which are vulnerable to endangerment in the near future.

**Endangered** - A species is in danger of extinction throughout all or a significant portion of its range.

**Range** - How widely organisms are distributed.

**Abundance** – Total count.

**LC** – Lethal Concentration Level of a particular parameter, defined in percentage of population die off.

**Resource allocation –** Long-lived organisms will use available resources in the most economic way for survival.

**Impacts** – Changes; can be positive or negative.

***Essential Questions:***

How can humans affect the stability of aquatic ecosystems?
How can humans impact the productivity and longevity of aquatic ecosystems?

***Topical Questions:***

What is a solution to low flow and dissolved oxygen in Barton Springs?

***Objectives***

Students will be able to:

- Identify the relationship between flow and DO;
- Identify the relationship between DO and salamander populations;
- Develop viable solution to low oxygen related to low spring discharge.

## Teacher Management

**Estimated Time for Completion**

50 minutes

**Materials**

Austin Underground Video www.ci.austin.tx.us/watershed/groundwater_threats.htm
For use with ELMO: "The Barton Springs Complex," "Eliza Springs," and graphs Figure 1 and 2
Student Copies: "Drought Impacts to the Barton Springs Salamander," "Student Sheet," "Peer Review"

**Teacher Prep** Make student copies. Have ELMO ready.

**Safety Considerations** None

**Vocabulary Building Strategies** TBD

**Background Information for Teacher**

The Barton Springs Salamander (*Eurycea sosorum*) is a small (1/2" to 3" long), solely aquatic, perennibranchiate (retaining juvenile characteristics, such as gills, throughout its life) salamander. It is unique in many ways, but of primary importance is its geographic range: the only place in the world these salamanders are found is at Barton Springs, in Austin, Texas.

Although some of the first specimens of the Barton Springs Salamander were collected in 1946, the species was not formally described until 1993. The salamander was given the taxonomic name, *Eurycea sosorum*, in honor of the citizens of Austin, who initiated and passed the SOS (Save Our Springs) Ordinance in 1992 to protect the aquifer that discharges at Barton Springs.

The Barton Springs Salamander only occurs in four springs, collectively known as Barton Springs, in Zilker Park. This includes Parthenia Spring within the popular swimming hole, Barton Springs Pool, and three other springs: Eliza, Sunken Garden, and Upper Barton (reference pictures at end of this section) that are off limits to the public. This report focuses on the salamander population at Eliza Springs.

More information about the Barton Springs salamander can be found at
http://www.ci.austin.tx.us/watershed/salamander.htm

**FAQ's**

1) Do adult salamanders care for their young? No

2) Where does funding for the salamander program come from? The City of Austin is required to provide protection for the salamander under the Endangered Species Act. City drinking water customers pay a drainage utility fee that provides funds for the salamanders and other watershed protection activities.

3) How are salamanders counted? Surveys to monitor the population size of the Barton Springs Salamander are conducted on a monthly basis at each spring site. During these surveys, biologists carefully search the available habitat by removing stones and cover objects down to a solid base (concrete, bedrock or compacted sediment) where the salamanders are typically living. Each salamander observed is categorized based on its size. Surveys are done in a systematic fashion to avoid counting any salamanders twice (drive survey technique). Additional information is also recorded during these surveys, such as presence and abundance of benthic macroinvertebrates, and various measurements of water quality.

4) Is the $LC_5$ of 4.5 mg/L of dissolved oxygen an average? No, it is a cumulative total over 28 days. In other words, in a laboratory setting, five percent of the total number of salamanders died when the DO level was held at 4.5 mg/L for a 28 day period.

5) How is spring flow measured? Scientists measure water velocity and depth at fixed distances across the spring discharge channel, then sum the product of those interval values for a total discharge..
The equation for each interval is: Water velocity (or speed) in ft/sec, X water depth in ft, X width of the measuring interval in ft = discharge in $ft^3$/sec, or cubic feet per second. This is typically noted as cfs.

**Misconceptions**

It is often believed:

- That the limits and strategies in effect are enough to protect the Barton Springs Salamander under all conditions. The relation of low spring flow to unacceptable low dissolved oxygen levels during the last couple of droughts indicate that different limits and strategies might need to be implemented during drought.
- *Eurycea sosorum* is an endangered species under federal protection so nothing can be done to harm it. Endangered Species Act ensures survival of species into perpetuity. It is not a “no take” (no mortality) policy. This means that although some salamanders may die due to anthropogenic impacts, their survival as a species cannot be compromised.
- Mortality is the only concern, not reproduction. Reproduction is a concern because the ESA requires survival of the species into perpetuity.

# The Barton Springs Complex

# SUNKEN GARDENS SPRING

# ELIZA SPRING

## **FOCUS ACTIVITY/WARM UP** (5 min)

View video segment on salamanders www.ci.austin.tx.us/watershed/groundwater_threats.htm

## **ENGAGE :** (5 min) (Display picture of "The Barton Springs Complex")

The Barton Springs Salamander (*Eurycea sosorum* or *E. sosorum* for short) only occurs in four springs, collectively known as Barton Springs, in Zilker Park. This includes Parthenia Spring within the popular swimming hole, Barton Springs Pool, and three other springs (Eliza, Sunken Garden and Upper Barton) that are off limits to the public.

**ENDANGERED SPECIES**

On April 30, 1997 the U.S. Fish and Wildlife Service (USFWS) added the Barton Springs Salamander to the list of endangered wildlife which receives federal protection under the Endangered Species Act (ESA). This act was passed in 1973 to "protect and recover imperiled species and the ecosystems upon which they depend."

Under the ESA, species may be listed as either endangered or threatened. "Endangered" means a species is in danger of extinction throughout all or a significant portion of its range. "Threatened" means a species is likely to become endangered within the foreseeable future. This listing is based specifically on each species' biological status and threats to their existence.

- Biological status for any species is determined by two factors:
  1) The range of the species, or how widely distributed the organisms are;
  2) The abundance or total numbers of the organisms.
  For E.sosorum this status is particularly precarious, because of its extremely limited range to spring upwellings at Barton Springs.
- Threats to *E. sosorums'* existence fit in the following two categories:
  1) Aquifer water quality - Barton Springs' water quality is dependant on surface conditions in the narrow geographic area of the Barton Springs Recharge Zone, a 9 by 20 mile area. Anthropogenic changes in this area can affect the aquifer's water quality and have significant impacts to the salamander.
  2) Aquifer water quantity - With its extremely limited range, the survival of this species is inextricably linked with the amount of water in the aquifer and the related volume of spring flow in the four springs. Although the region has experienced severe drought in the past, current pumping from the aquifer adds a unique stress to the system.

Important Point: Endangered Species Act ensures survival of species into perpetuity. It is not a "no take" (no mortality) policy. This means that although some salamanders may die due to anthropogenic impacts, their survival as a species cannot be compromised.

## **EXPLORE:** (20 min): Students will read report, "Drought Impacts to the Barton Springs Salamander," and complete Student Sheet, Part 1. Students work in groups to complete Part 2.

## **EXPLAIN:** (10 min) (Use photo of Eliza Springs and graphs, Figure 1 and 2)

**Drought, Discharge, And Dissolved Oxygen –** Drought decreases spring discharge or flow. Decreases in discharge are associated with reduction in current velocity of surface spring water and generally causedecreases in dissolved oxygen in the water.. In addition, the maximum concentration of oxygen that can be dissolved in water is inversely dependent on water temperature (Boyle's Law); so the warmer the water, the less dissolved oxygen it can hold. Since dissolved oxygen influences every aspect of the aquatic community, drought-related reductions in spring discharge can have strong effects on resident flora and fauna.

**LC = Lethal Concentration levels:** Percent mortality at a specific concentration of the substance being studied. For dissolved oxygen, concentration is measured in milligram per liter (mg/l). The LC subscript number represents the percent of organisms that die during the specified study time period. Thus a 28-day $LC_5$ threshold of 4.5 mg/L dissolved oxygen (DO) for adult survival means that 5 % of the adult salamanders die when subjected to 4.5 mg/L DO over a period of 28 days.

**Surrogate –** *E. nana* is a salamander that is similar to *E sosorum* but is not endangered, so it is used as a substitute, or surrogate, for *E. sosorum* in laboratory trials studying the LC for DO. The 28-day Lethal Concentration ($LC_5$) level of dissolved oxygen for adult survival of E. nana is 4.5 mg/L, so it is assumed this is the same for E. sosorum.

**Assessment of impacts**: Mortality occurs at or below at LC thresholds. Values above the LC threshold can still impact abundance- for example, reproduction can stop or decrease as salamanders allocate energy to simply surviving.

**Resource allocation –** Animals allocate metabolic energy according to environmental condition; one possible result is they don't reproduce when resources are low. Dissolved oxygen sustains animal life because it is used to convert food into metabolic energy. Both survival and reproduction depend on metabolic energy; its allocation to each depends on the amount of oxygen available and the life history of the animal. For long-lived animals that reproduce more than once in a lifetime such as *E. sosorum*, when dissolved oxygen is high, metabolic energy can be created in abundance, and allocated to both survival *and* reproduction. Conversely, when dissolved oxygen is low, metabolic energy is limited and generally will be allocated to survival. Reproduction is delayed until environmental conditions improve.

**EXTEND/ELABORATE** (10 min.):

(Student Sheet, Part 3) - In groups, design a solution that addresses the anthropogenic impacts of drought to *E. sosorum*. Emphasize that the solution needs to address the criteria of DO, flow, or temperature.

**EVALUATE**

Give your solution to a different group to evaluate criteria. (Peer Review)
Revise your solution based on feedback. (Student Sheet, Part 5)

## CLOSURE/DAILY ASSESSMENT

Student solutions

# Salamander Threats/Solutions
## ANSWER SHEET

## PART 1

1) What is the scientific name of the Barton Springs salamander? ***Eurycea sosorum or abbreviated E. sosorum***

2) Define anthropogenic. ***Effects, processes, or materials that are derived from [human](human) activities, as opposed to those occurring in [biophysical environments](biophysical environments) without human influence***

3) What is the trigger level for drought at Barton Springs? ***Less than 40 cubic feet per second***

4) What does $LC_5$ mean? ***5% of the adult salamanders die when subjected to 4.5 mg/L DO over a period of 28 days***

5) Does warmer water or cooler water dissolve more oxygen (DO)? ***Cooler water***

## PART 2

Figure 1:

1. Interpret graphing symbols:
   a. What do the shaded areas represent? ***Drought***

   b. What do the black diamonds represent? ***DO or dissolved oxygen***

   c. What part of the graph shows Barton Springs discharge? ***The solid line***

2. Compare the drought of 2005-06 to that in 2008-09:
   a. Which drought had the longest period of lowest discharge? 2008-2009

   b. What was the lowest discharge recorded during either of these periods? ***10 -11 ft.3/sec.***

   c. What was the lowest DO in either one? ***4 mg/L***

3. Determine pre-drought data points:
   a. From 2003-2005, what was the highest DO recorded? ***7.5 mg/L***

   b. Approximately how much discharge was recorded at that same time***? 100 ft.3/sec***.
4. In general, is the relationship between discharge and DO a direct one (they 'track' together) or an inverse one (they move in opposite directions)?
   ***It is a direct relationship - discharge and DO track together***

Figure 2:

5. a. Right before the drought of 2008-09, what was the DO level? *7.7 or 7.8 mg/L*

   b. What was the number of adult salamanders? ***650***

   c. What was the number of juvenile salamanders? ***500***

6. During the drought of 08-09, how many DO measurements were below 4.5 mg/L? ***10***

7. a. What is the very last DO measurement on this graph? ***8 mg/L***

b. How many adult salamanders were counted at that time? ***375***

c. How many juveniles? ***0***

Conclusions:

8. What happened to the salamander population numbers during the period of time when the DO was below the LC5 level? ***The number of salamanders dropped***

9. After the severe drought of 2008-2009, adult salamanders started to rebound, but juveniles did not. What does this indicate about the effects of drought on salamander reproduction?
***Salamanders do not reproduce, but allocate their resources for survival***

10. Explain how dissolved oxygen can still limit salamander populations even when levels are not low enough to kill any organisms. ***Salamander populations can decline if the DO is too low for salamanders to allocate resources for reproduction***

## PART 3

**Step 1**: List three anthropogenic activities that increase the impacts of drought to salamanders.
***Wells pumping water from the aquifer, impervious cover, non-point source pollution in recharge areas and dams***

**Step 2:** Take into consideration criteria such as dissolved oxygen, spring discharge and temperature to develop a solution that addresses the impacts of drought to *E. sosorum*. ***Any acceptable answer that considers the criteria***

**Step 3:** Take into consideration as criteria the cost to taxpayers of your solution and the impact of public acceptance to revise your solution as necessary. ***Any acceptable answer that includes cost and public acceptance***

# REPORT--Drought Impacts to the Barton Springs Salamander

(Adapted from 2010 report by Laurie Dries, PhD, City of Austin salamander biologist)

The Barton Springs Salamander (*Eurycea sosorum* or abbreviated *E. sosorum)* only occurs in four springs, collectively called the Barton Springs complex. This includes Parthenia Spring within the popular swimming hole, Barton Springs Pool, and three other springs (Eliza, Sunken Garden, and Upper Barton) that are off limits to the public.

This report focuses on the salamander populations at Eliza Springs because the abundance of salamanders at Eliza provides the best information from which to infer population status of the Barton Springs Salamander because of:

1) The smaller size of this spring (~ 800 sq. ft.) which allows the entire surface habitat to be searched during every survey, and

2) The presence of a concrete floor below surface substrate which limits salamander access to the sub-surface, allowing for greater detection of salamanders if present.

## SALAMANDER ABUNDANCE

There have been dramatic changes in *E. sosorum* abundance at Eliza Springs due to anthropogenic effects (processes or materials that are derived from human activities) and natural factors. The positive anthropogenic factor was habitat reconstruction of the spring pool in 2003, which was followed by large increases in salamander abundance.

The most detrimental "semi-natural" factor since 2003 affecting abundance was the severe drought of June 2008 – September 2009. During this period, there were statistically significant decreases in total salamander abundance relative to the 2003 – May 2008 period. Juvenile and adult abundances were significantly lower during the drought, while young adult abundance was not.

## DROUGHT

When discharge drops below 40 cubic feet per second (cfs) at Barton Springs, Upper Barton Springs is dry, a condition that signifies habitat restriction. Therefore, discharge below 40 cfs is drought conditions at Barton Springs.

- October 2005-October 2006: discharge dropped to low of 24 cfs.
- June 2008 – September 2009: discharge dropped to low of 13 cfs.

At all three perennial spring sites of the Barton Springs complex, which includes Eliza, drought conditions are increased by dams and other concrete structures.

Although lack of rainfall feeding the aquifer is part of natural climatic variation, pumping of groundwater by humans is not. There are growing cities that draw groundwater from the Barton Springs segment of the Edwards Aquifer under all conditions. Therefore, we consider droughts that affect the Barton Springs complex semi-natural factors because their severity can be affected by this anthropogenic activity.

## DROUGHT DATA FROM ELIZA SPRINGS (Figure 1)

Figure 1 shows the drought's effects on *E. sosorum's* habitat, evident in the reduction of dissolved oxygen, increases in water temperature, and decreases in discharge. Decreases in discharge (flow) generally causes decreases in dissolved oxygen in rivers and streams. In addition, the maximum concentration of oxygen that can be dissolved in water is inversely dependent on water temperature; e.g. the warmer the water, the less dissolved oxygen it can hold.  Since dissolved oxygen influences every aspect of the aquatic community, drought-related reductions in spring discharge can have strong effects on resident plants and animals.

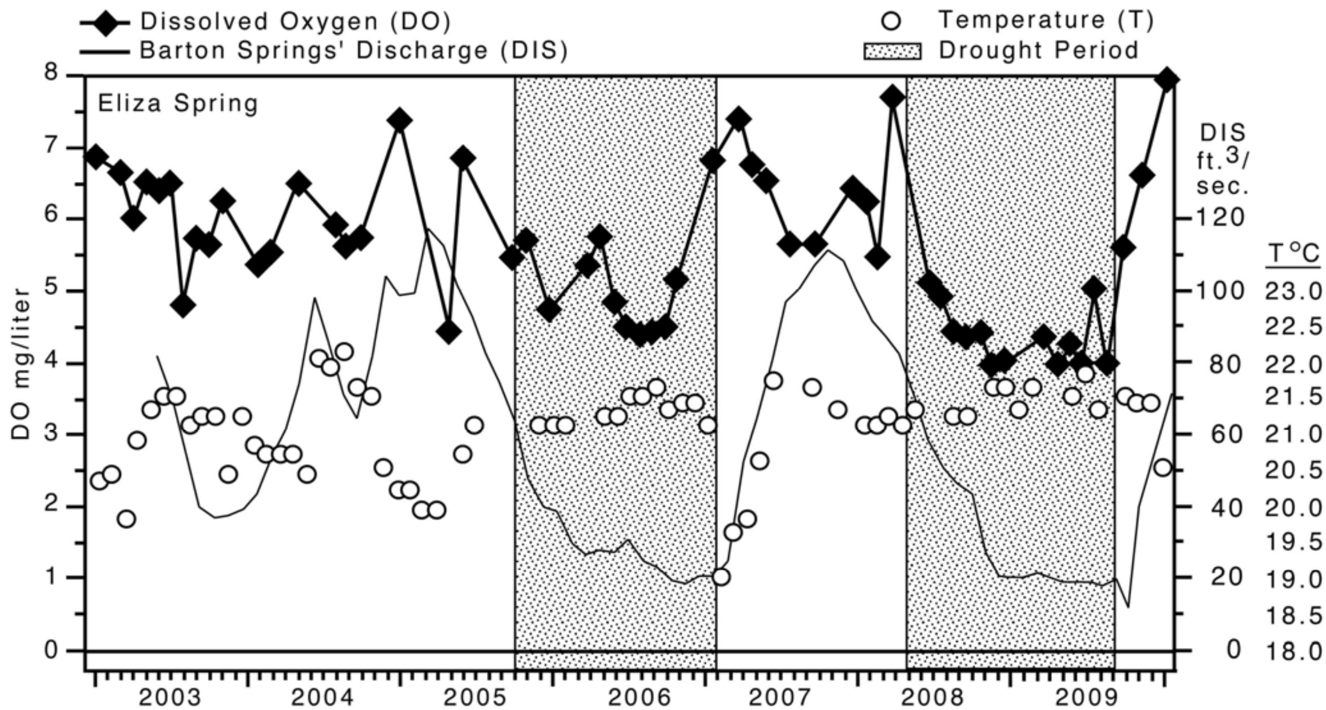


Figure 1 -  Barton Springs discharge in cubic feet per second (cfs),  Eliza Spring dissolved oxygen in milligrams per liter (mg/L) and temperature in degrees Celsius.  Shaded area on X axis indicates periods of drought.

## DROUGHT IMPACTS TO ELIZA SPRING'S SALAMANDERS (Figure 2)

The mean dissolved oxygen during the drought was below the 28 day Lethal Concentration ($LC_5$) level of 4.5 milligrams per liter (mg/L), (which means 5 % of the adult salamanders die when subjected to 4.5 mg/L DO over a period of 28 days). Dissolved oxygen also fell below the 60-day threshold of 4.44 mg/L at which growth of juvenile salamanders is compromised.

The post drought data results represent a 98% decrease in juvenile abundance over 16 months (see Figure 2), suggesting that drought was most detrimental to juveniles.  The very small numbers of juveniles from October through December of 2009 also suggests that during the drought, adult salamanders did not reproduce.

This is consistent with other studies that have found when environmental conditions are poor, adults allocate metabolic energy to merely surviving, rather than reproducing.

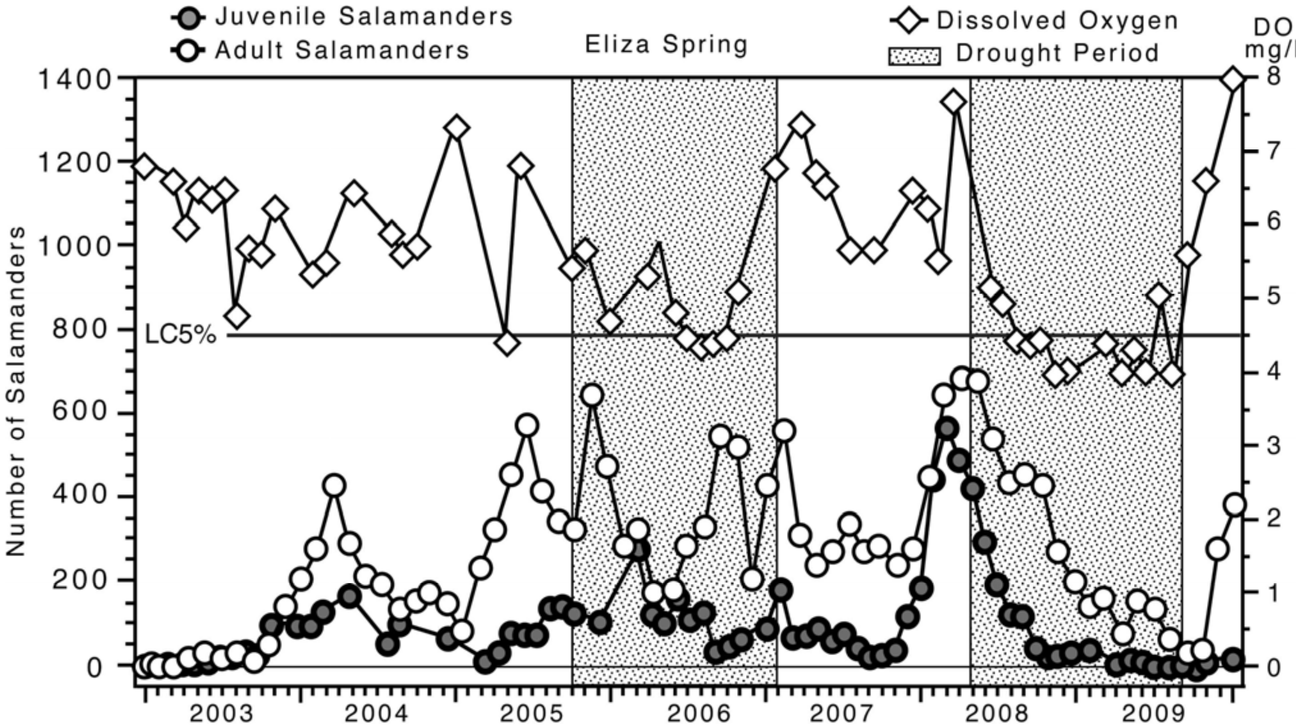


Figure 2 - Eliza Springs dissolved oxygen concentrations, *E sosorum* abundances, with juveniles and adults shown by dark and open circles respectively. Arrow indicates extremely low abundance of juveniles after the 08/09 drought. Black lines indicating LC 5% represent the dissolved oxygen concentrations at which that percent (5 %) of *E. nana* (a surrogate species) die after 28 days of exposure.

## CURRENT SALAMANDER AND AQUIFER PROTECTIONS DURING DROUGHT

- Supplement dissolved oxygen at the Barton Spring complex by aerating and circulating the water.
- Salamander Captive Breeding Program
  www.ci.austin.tx.us/watershed/captive_breeding.htm
- Voluntary pumping limits for historical (pre 2009) well permit holders.
- Mandatory pumping limits for well permits since 2009.
  (See www.bseacd.org/regulatory/drought-management/ for drought stages and pumping limits)
- Beginning in 1991, 15% impervious cover limits for new construction in the Barton Springs Recharge Zone. Areas approved for development before 1991 do not have to comply.
- Recharge Feature protection – caves, sinkholes, fractures and other significant openings into the aquifer require a 150 ft. setback from any development.

**CONCLUSION:** The relation of low spring flow to unacceptable low dissolved oxygen levels during the last two droughts indicate that different limits and strategies might need to be implemented during drought.

Name:________________________

Period:___________

# STUDENT SHEET

**PART 1**

**Purpose:** To understand the impact of drought on *E. sosorum* populations and the increased stress from anthropogenic sources.

**Step 1:** Read the report "Drought Impact to the Barton Springs Salamander" by City of Austin salamander biologist Laurie Dries.

**Step 2:** Answer questions 1-5

1) What is the scientific name of the Barton Springs salamander? __________________________

2) Define anthropogenic. ____________________________________________________________

3) What is the trigger level for drought at Barton Springs? _________________________________

4) What does $LC_5$ mean? _______________________________________________________________

5) Does warmer water or cooler water result in higher dissolved oxygen (DO) levels? _________

**PART 2**

**Purpose:** To interpret graphs and make conclusions based on data.

**Step 1:** Review Figures 1&2

**Step 2:** Work with other students to answer questions 1-4 (Figure 1) and 5-10 (Figure 2).

## Interpret Figure 1:

1. Interpret graphing symbols:
   a. What do the shaded areas represent? __________________________________________

   b. What do the black diamonds represent? ________________________________________

   c. How is Barton Springs discharge represented on the graph?_______________________

2. Compare the drought of 2005-06 to that in 2008-09:
   a. Which drought had the longest period of lowest discharge? _______________________

   b. What was the lowest discharge recorded during either of these periods? _____________

   c. What was the lowest DO in either one? __________ mg/L

3. Determine pre-drought data points:
   a. From 2003-2005, what was the highest DO recorded? _________ mg/L

   b. Approximately how much discharge was recorded at that same time? ____________

4. In general, is the relationship between discharge and DO a direct one (they 'track' together) or an inverse one (they move in opposite directions)?

_____________________________________________________________________________

**<u>Interpret Figure 2:</u>**

5. a. Right before the drought of 2008-09, what was the DO level? ________mg/L
   b. What was the number of adult salamanders? ___________
   c. What was the number of juvenile salamanders? _________

6. During the drought of 08-09, how many DO measurements were below 4.5 mg/L?__________

7. a. What is the very last DO measurement on this graph? __________ mg/L
   b. How many adult salamanders were counted at that time? ___________
   c. How many juveniles? ____________

**Conclusions:**

8. What happened to the salamander population numbers (both adult and juveniles) during the period of time when the DO was below the LC5 level?

________________________________________________________________________

9. After the severe drought of 2008-2009, adult salamanders started to rebound, but juveniles did not. What does this indicate about the effects of drought on salamander reproduction?

________________________________________________________________________

10. Explain how dissolved oxygen can still limit salamander populations even when levels are not low enough to kill any organisms.

________________________________________________________________________

**PART 3**

**Purpose:** To design a solution that addresses the anthropogenic impacts of drought to *E. sosorum*. Work in group.

**Step 1**: List three anthropogenic activities that increase the impacts of drought to salamanders.

________________________________________________________________________

**Step 2:** Using at least **one** of the following criteria: dissolved oxygen, spring discharge and/or temperature, develop a solution that addresses the impacts of drought to *E. sosorum*.

________________________________________________________________________

________________________________________________________________________

**Step 3:** Now, describe how taxpayer cost and public acceptance may impact your solution and revise it accordingly.

________________________________________________________________________

________________________________________________________________________

**PART 4**

## Peer Review of Design Solutions to Salamander Impacts from Drought

**Evaluation Team Member Names: ________________________________________________**

What is the proposed solution? ______________________________________________________

_____________________________________________________________________________

Will the solution increase DO? _______

Will the solution increase spring discharge? _______

Will the solution maintain temperature within ideal range for *E. sosorum*? ________

**Considering that solutions are paid for by City of Austin taxpayers:**

Do you estimate the solution to be cost prohibitive or cost effective?

_____________________________________________________________________________

Do you think this solution will be easily accepted by Austin Citizens? Explain.

_____________________________________________________________________________

_____________________________________________________________________________

Additional comments: ___________________________________________________________

_____________________________________________________________________________

**PART 5**

**Purpose:** To evaluate and revise your proposed solution based on peer review.

**Step 1:** Give your solution to another team for peer review.

**Step 2:** Review a team's solution using the Peer Review Criteria sheet.

**Step 3:** Based on feedback, how would you change your original design?

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