Draft Habitat Conservation Plan for Managed Groundwater Withdrawals from the Barton Springs Segment of the Edwards Aquifer

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Barton Springs/Edwards Aquifer
Conservation District

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For:
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Under Direction of District Board of Directors:

DRAFT HABITAT CONSERVATION PLAN FOR MANAGED GROUNDWATER WITHDRAWALS FROM THE BARTON SPRINGS SEGMENT OF THE EDWARDS AQUIFER

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List of Acronyms, Abbreviations, and Terms Used in This Document

Act, the	The federal Endangered Species Act
AF	Acre-feet
AMP	Adaptive Management Plan
BAT	Biological Advisory Team
BSEACD	Barton Springs/Edwards Aquifer Conservation District
C	Celsius, temperature scale
CAC	Citizens Advisory Committee
CCSP	U.S. Climate Change Science Program
CFR	Code of Federal Regulations
cfs	cubic feet per second
CO2	carbon dioxide
COA	City of Austin
COMM	Commercial, water use type
DFC	Desired Future Condition
DISTRICT	Barton Springs/Edwards Aquifer Conservation District
DO	Dissolved Oxygen
DOI	U.S. Department of the Interior
DOR	Drought of Record
EAA	Edwards Aquifer Authority
EIS	Environmental Impact Statement
ERP	Emergency Response Period (drought stage)
ESA	Endangered Species Act (the Act)
FR	Federal Register
GBRA	Guadalupe-Blanco River Authority
GCD	Groundwater Conservation District
GCM	Global Circulation Model
GMA	Groundwater Management Area
GWSIM- IV	USGS groundwater flow model
HCP	Habitat Conservation Plan
ILA	Interlocal Agreement
IND	Industrial, water use type
IPCC	Intergovernmental Panel on Climate Change
IRG	Irrigation, water use type
ITP	Incidental Take Permit
LC_x	Lethal Concentration [x is percentage of total]
MAC	Management Advisory Committee;
MAG	Modeled Available Groundwater (derived from DFC)
MG	million gallons
mg/L	milligrams per liter (chemical concentration)

mm	millimeter
MP	[District] Management Plan
msl	mean sea level, datum for elevation measurement
NDU	Nonexempt Domestic Use
NEPA	National Environmental Policy Act
NOAEL	No Observed Adverse Effect Level
PEHA	Probabilistic Ecological Hazard Assessment
pH	Concentration of hydronium ion (acid-base measure)
Production	(Amount of) groundwater withdrawn by pumping water well(s)
PWS	Public Water Supply, water use type
Pumpage	Amount of groundwater pumped from water well(s)
r	Correlation Coefficient
R^2	Coefficient of Determination
SAP	Synthesis and Assessment Product
SD	Standard Deviation
Service	U.S. Fish and Wildlife Service, Department of the Interior
SYS	Sustainable Yield Study
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TPWD	Texas Parks & Wildlife Department
TWC	Texas Water Code
TWDB	Texas Water Development Board
UCP	User Conservation Plan
UDCP	User Drought Contingency Plan
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Withdrawal(s)	Groundwater withdrawn from aquifer by pumping water well(s)

Acknowledgments

The Barton Springs/Edwards Aquifer Conservation District (BSEACD) prepared and is submitting the Habitat Conservation Plan (HCP) as the sole Plan Participant, and the BSEACD alone is responsible for the contents of the HCP . However, the BSEACD was assisted in the preparation of various drafts of the HCP and in the conduct of supporting investigations by a set of contractors that provided important contributions to the overall effort. The contractors are:

- Hicks & Company, for environmental impact assessment and NEPA-related documentation;
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- LBG-Guyton Associates, for hydrogeological consultation;
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- Peter Bush, Technical Editor.

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Moreover, the District has assembled a multilateral stakeholder group to serve as a continuing HCP Management Advisory Committee (MAC) to advise the District Board of Directors and assist the District staff in implementing the HCP, as described in Section 6.5.1.2, District HCP Management Advisory Committee. The inaugural members of the MAC also participated in a comprehensive, facilitated review process of earlier versions of the HCP, and their comments substantially improved the final draft document. These members and their affiliations/interest groups are:

Brian Smith	BSEACD Aquifer Science Team (District Technical Staff)
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David Loftis	Centex Materials (Large Private Sector Permittee)
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Christy Muse	Hill Country Alliance (Private Property Conservation Interests)
Todd Votteler	Guadalupe Blanco River Authority (River Authority)
Jon White	Travis County (County Government)
Clif Ladd	Interested Private Citizen (Public At-Large)
Karen Huber	Interested Private Citizen (Public At-Large)

The District sincerely appreciates the past and future contributions of the many individuals who selflessly give their time and perspectives to benefit this HCP and the public interest.

Draft Habitat Conservation Plan for Managed Groundwater Withdrawals from the Barton Springs Segment of the Edwards Aquifer

1.0 Introduction and Background

This habitat conservation plan (HCP) is proposed by the Barton Springs/Edwards Aquifer Conservation District (BSEACD, or the District) in support of an application for an incidental take permit (ITP, or Permit) from the U.S. Fish and Wildlife Service (Service) for the Barton Springs salamander, *Eurycea sosorum* , and for the Austin blind salamander, *E. waterlooensis*, both protected species listed as endangered by the Service (together, the Covered Species). The term "take" refers to an action and its associated adverse effects on members of any threatened or endangered species. The District is a political subdivision of the State of Texas, a local agency of the State that was formed and authorized by the Texas Legislature specifically to manage the groundwater resources within its jurisdiction under applicable state laws and statutes, particularly Texas Water Code Chapter 36 and Special District Local Laws Code Chapter 8802. This document constitutes the HCP for the regulated withdrawal of groundwater of the Barton Springs segment of the Edwards Aquifer as a water supply by permitted well owners/operators under the conservation program and auspices of the District (hereinafter, District HCP). It proposes a substantial number of regulatory and groundwater management measures that will be implemented by the District as HCP conservation measures upon issuance of an ITP under Section 10 of the Endangered Species Act (Act).

Issuance of an ITP is a federal action subject to a review by the Service in compliance with the National Environmental Policy Act (NEPA), which may involve preparation and further documentation of overall environmental consequences in an Environmental Assessment or Environmental Impact Statement. The District HCP focuses exclusively on the biological and ecological effects and consequences of certain District actions as they relate specifically to the Covered Species. A separate NEPA document presents the Service's analysis of the direct, indirect, and cumulative impacts of issuing the requested ITP on all of the natural and the man-made environments.

The District HCP is a public document under the Texas Public Information Act. It is the District's intent that this document provides such additional context and information, beyond that required by the Service, to be comprehensible and useful to the District's stakeholders, including District permittees and the state, regional, and local entities affecting and affected by the HCP. However, an HCP is essentially a proposal to the Service that informs a Service-internal consultation process specifically designed to form a Biological Opinion on the likely effects and consequential impacts on the Covered Species, which then becomes the basis for decision-making on issuance of an ITP. As such, its format, content, and level of detail are largely prescribed by Service regulations, policy, and guidance.

The District's statutory mandate is to provide for the conservation, preservation, and protection of groundwater resources of all aquifers in its jurisdictional area, including parts of northwestern Caldwell, northeastern Hays, and southeastern Travis Counties. This area encompasses all sites of groundwater withdrawal from the Barton Springs segment of the Edwards Aquifer, sometimes called the Barton Springs aquifer (hereinafter, the Aquifer, unless narrative context requires additional specificity). This mandate is consistent with the HCP; and the same measures that benefit the Aquifer's human users, by extending the water supply during drought, also benefit the Covered Species that depend on the Aquifer as habitat.

The District's activities described by this HCP are consistent with current (2014) statutory authorities of the District and are based on sound science and effective groundwater management practices. They have been formulated and framed in collaboration with other conservation efforts affecting the Covered Species and/or their habitat. In particular this includes the City of Austin's (COA) July 2013 "Major Amendment and Extension of the Habitat Conservation Plan for the Barton Springs Salamander (*Eurycea sosorum*) and the Austin Blind Salamander (*Eurycea waterlooensis*) to Allow for the Operation and Maintenance of Barton Springs and Adjacent Springs" (hereinafter, the Barton Springs Pool HCP). Certain aspects of the Edwards Aquifer Recovery Implementation Plan/HCP for the use and management of the adjacent San Antonio segment of the Edwards Aquifer (EARIP, 2012) were relevant to and useful in developing the District's HCP.

The biological goals and objectives of the District's conservation program are listed in Section 6.1, Biological Goals and Objectives of the HCP. Other District goals and objectives are characterized in the current Texas Water Development Board (TWDB)-approved District Management Plan (BSEACD, 2013) and are complementary to and consistent with the goals and objectives described in this HCP.

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2.0 Purpose and Need for HCP/ITP

2.1 Purpose

As described above, the District's statutory mandate is to provide for the conservation, preservation, and protection of groundwater resources of all aquifers in its jurisdictional area. Certain activities associated with that mission may produce both beneficial and adverse effects on the rate and water chemistry of springflow at Barton Springs that in turn impact the habitats of the Covered Species. In particular, the District's drought management program both allows and restricts the amount of groundwater withdrawn from the Aquifer by certain well owners. Nevertheless, the federal Endangered Species Act (Act) prohibits take of its listed species except as prescribed in the Act. The purpose of the District HCP is to meet the requirements of applying for and receiving an ITP under the Act (see Section 2.2.2, Statutory Basis of Need: Endangered Species Act). The purpose of the ITP is to allow the District, on a federally authorized exception basis, to continue to carry out its State-authorized, otherwise lawful activities that may result in incidental take of the Covered Species.[1]

2.2 Need

2.2.1 Programmatic Basis of Need

The District's activities that create the need for an HCP and an ITP relate to the following groundwater management functions that are explained in the District Management Plan (District, 2013):

- Adopt, implement, and enforce regulations and management programs that protect existing groundwater supplies, improve aquifer demand management, provide Aquifer and springflow protection during droughts, promote and improve aquifer recharge, and carry out other beneficial management strategies; and

- Avoid, or minimize, and mitigate negative impacts upon federally listed species dependent upon springflow from Barton Springs through adoption and implementation of regulations, management programs, scientific research programs, conservation education programs, and collaborative efforts with other governmental entities.

These activities directly and indirectly affect withdrawals (pumpage) from the Aquifer (the amount of groundwater withdrawn by operating pumps set in wells [pumping wells] installed within the Aquifer for providing the water supply of well owners/operators). In turn, as a result of the hydrology of the groundwater system, such withdrawals lower the elevation (altitude referenced to mean sea level) of water levels in the Aquifer, which consequently reduces the

[1] The Covered Species may also be stressed by the introduction of pollutants that affect the quality of water recharging the Aquifer. Unlike the natural water chemistry changes, these water quality impacts are generally caused by human activities on the land surface that result in pollution from point sources and especially nonpoint sources. In this document, these impacts are referred to as "water quality" impacts, to distinguish them from "water chemistry" impacts. The water quality impacts of these actions, over which the District has no control and therefore are not Covered Activities, are cumulative with the natural changes in water chemistry associated with lower springflows, and both are generally antagonistic to aquatic life requirements.

discharge (springflow, or flow) at Barton Springs. There is a well-established relationship, within the observed data range, between the flow issuing from the outlets of Barton Springs and the chemistry of the water. As flow decreases, the dissolved oxygen (DO) concentration of the water, which is required by the Covered Species for survival, decreases, and the concentration of dissolved solids increases. This natural variation in water chemistry derives from the physical system of the Aquifer, and it occurs regardless of whether springflow decreases are due to drought, withdrawals by wells, or both (BSEACD, 2013; BSEACD, 2004).

During normal and high-flow conditions in the Aquifer, the combined flow of the natural outlets at Barton Springs are many multiples of the total amount of water that is being withdrawn by wells in the Aquifer. Under these conditions, the District's program elements principally address the long-term sustainability of the Aquifer as a water supply. Under these conditions, the amount of water withdrawn from the Aquifer by wells and the provisions of the District's regulatory program are believed to have essentially no effect on the chemistry of the springflow. This is because the physical and chemical characteristics of the springflow are mostly attributable to meteorologically induced stormflows and seasonal factors, and from time to time, other external factors (Mahler and Bourgeais, 2013; Mahler et al., 2011). Accordingly, essentially no incidental take is attributable to the Covered Activities (lawfully conducted withdrawals from District permitted wells, see Section 4.1, Proposed Covered Activities) when water levels in the Aquifer are above a certain elevation, which determines the flow at the Aquifer's major outlet, Barton Springs. This threshold elevation and flow are characterized in Section 3.2.2.1, Physical Setting.

But during drought, and especially prolonged severe drought[2], the amount of water naturally discharging from the springs complex (the natural spring outlets taken together) is much smaller, similar in magnitude to the amount of water withdrawn from wells. During these drought conditions, the District's groundwater drought management program is key to preserving groundwater levels in the Aquifer and springflow. The joint and regional water planning conducted by the State, with which the District's groundwater management plan is integrated, uses a recurrence of the drought of record in the 1950s (DOR) as the planning objective, and the DOR is also the framework for the District's drought management program. The District's integrated regulatory program is designed to protect the water supply of Aquifer users who are most vulnerable to supply interruption during periods of Extreme Drought and to conserve the flows at Barton Springs for both ecological and recreational purposes. It is during certain of these drought periods that the groundwater levels and springflows unavoidably decline sufficiently to create incidental take of the Covered Species, which creates the programmatic need for the HCP and the ITP. The circumstances that give rise to such incidental take are discussed in detail in Section 5.2.2, Spatial and Temporal Extent of Take, and Section 5.2.3, Consideration of Take and Jeopardy.

Demand for and withdrawal of groundwater for public water supply and other beneficial uses have increased substantially in recent decades, which in turn increase the need for programmatic action. For many users, the Aquifer continues to be the only feasible water supply available. The

[2] "Severe drought" is a general term used herein to refer qualitatively to conditions that represent those groundwater drought conditions in the District that range from prolonged Stage II-Alarm through Stage IV-Exceptional droughts, as defined and declared by the District. See Appendices E, F, and G for more information on drought stage definition and drought management implementation.

cumulative withdrawals of all operating wells in the Aquifer can have significant impact on springflow during drought conditions and can increase the likelihood of low-flow conditions. During severe drought, the impact of withdrawals may produce habitat-significant water chemistry changes, as will be characterized in Section 3.2.2.2, Ecological Setting. The withdrawal from permitted operating wells reached an all-time monthly peak of approximately 13.4 cubic feet per second (cfs) (equivalent to 3.21 billion gallons per year) in June 2008 (BSEACD, unpublished data, 2014).

Since June 2008, despite increased demand for water supplies in the District, withdrawals generally have been reduced as a result of groundwater management policies and regulations of the District and of responses by its permittees to projected shortfalls during severe droughts. As the demand for groundwater has increased, the District has gradually changed its drought management and regulatory program to improve the effectiveness of Aquifer and springflow protection, supported in no small part by the studies and planning for the ongoing HCP development. Monthly average pumpage for the 3 years 2007–09 was 8.2 cfs, which also included a regulated drought period in 2008–09 with mandatory pumpage reductions of 20 and 30% during District-declared Stage II-Alarm and Stage III-Critical drought, respectively (BSEACD, 2010). Withdrawals were once predicted to increase steadily with urban development over the Aquifer and reach as much as 19.6 cfs by 2050 (Scanlon et al., 2001). However, owing to the implementation of conservation plans, demand-management programs, and imposition of severe drought-withdrawal limitations by the District (described in Section 6.2, Minimization and Mitigation Measures), the estimated maximum withdrawals over the long term are now considerably lower, no more than 25% of that previously projected peak of 19.6 cfs.

The HCP specifies the District commitments to a set of conservation (avoidance, minimization, and mitigation) measures that are consistent with statutory authorities of the District and that are based on sound science and effective groundwater management practices. The District HCP has been formulated and framed in collaboration with other conservation efforts affecting the Covered Species and their respective habitats; that is, the habitat conservation plan of the COA for operation and maintenance at Barton Springs Pool and surrounding area, including particularly the individual spring outlets (Barton Springs Pool HCP). The well owners and users, especially the District's permittees as described in Section 4.1.1 (The Regulated Groundwater Community), and all citizens who consider Barton Springs an ecological, recreational, and aesthetic resource, are the key additional stakeholders for this HCP.

2.2.2 Statutory Basis of Need: Endangered Species Act

The Act, spelled out in Title 50, Chapter I, Subchapter B, Part 17, Subpart A, Section 17.3 of the Code of Federal Regulations (50 CFR § 17.3), is the relevant federal statute that protects and promotes the recovery of endangered and threatened species. Section 9 of the Act (16 U.S. Code [USC] 1538(a)) prohibits "take" of any federally endangered wildlife. Take is defined as an action that may annoy, harm, harass, pursue, shoot, wound, hunt, kill, trap, capture, or collect members of any threatened or endangered species. Section 10(a)(1)(B) of the Act of 1973 (16 USC 1539(a)(1)(B)) authorizes the U.S. Fish & Wildlife Service (Service) to issue a permit (or ITP) allowing on a conditional and exception basis the take of protected species that is incidental to, and not the purpose of, the carrying out of otherwise lawfully conducted activities (Covered Activities). For the issuance of an ITP, the applicant must submit a conservation plan that satisfies the requirements of Section 10(a)(2)(A) of the Act. The required elements of an HCP and ITP under the Act are identified in Section 2.3, Correspondence between HCP Sections and Information Required by Service.

Section 10(a)(2)(B)(ii) of the Act allows non-federal entities to conduct otherwise lawful activities likely to cause take of endangered species, as long as the detrimental effects of the activities are not purposeful and are minimized and mitigated to the maximum extent practicable; and further provides that the Service determines that jeopardy of the Covered Species' populations related to the Covered Activities is avoided. "Jeopardy" occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the field is appreciably reduced. HCPs are the vehicles by which such take can be authorized by the Service on an exception basis, provided that it will be minimized and mitigated by the ITP applicant to the maximum extent practicable. This HCP is expressly designed to fulfill those obligations of the District for the regulated groundwater withdrawal from the Aquifer (its Covered Activities).

2.3 Correspondence between HCP Sections and Information Required by Service

The location of the information required or pertinent for an HCP to comply with Service regulations and guidance is tabulated in the following subsections. These correspondence tables are provided to assist not only the Service but also and especially the District's stakeholders and the public in finding and reviewing information that relates the descriptions of the District's groundwater management programs to the required conservation plan elements.

2.3.1 Information Requirements of an HCP in Support of an ITP

Service Requirement (16 USC § 1539(a)(2)(A)(i)-(iv)	HCP Section(s)
1. The impact that will likely result from the taking;	5.2; 5.3
2a. Steps the applicant will take to monitor, minimize, and mitigate such impacts,	6.0; 6.1; 6.2; 6.3; 6.4; 6.5.1; 7.1; 7.2.2
2b. The funding available to implement the steps, and	8.0
2c. The procedures to be used to deal with unforeseen circumstances;	7.3
3. Alternative actions to the proposed taking considered by the applicant and the reasons why such alternatives are not proposed to be used; and	9.0; 9.1; 9.2
4. Other measures that may be required or appropriate for the purposes of the plan.	None yet identified, but see 6.4; 6.5.1.3; 7.1

2.3.2 Findings for Service to Issue an ITP

Service Requirement (16 USC § 10(a)(2)(B)	HCP Section(s)
1. The taking will be incidental;	1.0; 2.1; 4.1
2. The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking;	6.0-6.4; 7.0-73; 9.2
3a. The applicant will ensure that adequate funding of the conservation plan [will be provided], and	8.0
3b. [The applicant will ensure that] procedures to deal with unforeseen circumstances will be provided;	7.2, 7.3
4. The taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild; and	5.1.3;.5.1.4; 5.2.3.4; 5.3
5. The applicant will ensure that other measures as may be required by Service as necessary or appropriate for purposes of the HCP will be implemented.	1.0; 4.1.2.1; 4.1.3; 6.1; 6.3; 6.4; 6.5.1; 7.0-7.3; 8.0

2.3.3 Additional Guidance and Recommendations for Developing HCPs ("Five Point Policy")

HCP Handbook Addendum (65 FR[3] 32,250-32,256)	HCP Section(s)
1. Defined conservation goals and objectives;	1.0; 6.1; 6.2
2. An adaptive management strategy;	6.4; 6.5.1.2; 6.5.1.3; 7.2; 7.3
3. Compliance and effectiveness monitoring;	6.3; 6.3.1- 6.3.4
4. An established permit duration; and	4.2
5. Opportunities for public participation.	4.1.3; 4.1.4

[3] Volume 65 of the Federal Register.

3.0 Description of Areas Analyzed

The geographic area of the HCP is in Central Texas. It is an area rich in the amount and variety of natural and human resources, but it is undergoing rapid suburbanization associated with burgeoning growth of the Austin-San Marcos metropolitan area. Land use and cultural aspects are converting from dominantly rural to dominantly suburban/commercial character (BSEACD, 2013).

Two areas are described in detail in this part of the HCP. The larger is the “Planning Area,” which includes the entire area that either affects or is affected by the HCP and in which mitigation measures could take place. The smaller is the “Incidental Take Permit Area,” or ITP Area, which is coincident with the District’s jurisdictional area. The ITP Area is where the Covered Activities of the District are and where any resulting incidental take of Covered Species occurs.

3.1 Planning Area

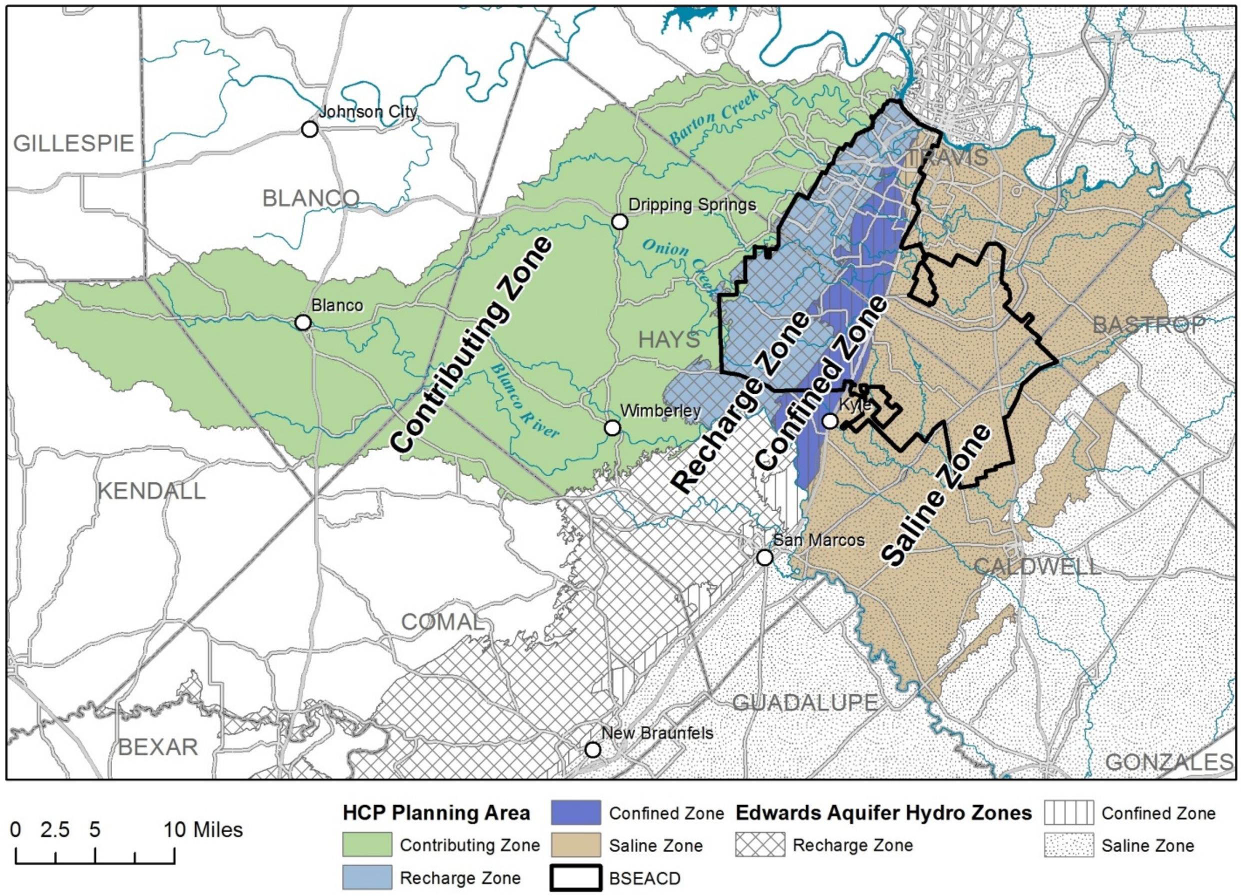
The Planning Area is shown in Figure 3-1. It encompasses the jurisdictional area of the District, which includes the Barton Springs complex (the four main outlets that together constitute Barton Springs), and the areas outside the District that contribute recharge to the Aquifer and use the Aquifer for water supply. The Planning Area also contains all of the wells in the Aquifer.

3.1.1 General Environmental Setting of Planning Area

The environmental setting of much of the Planning Area has been described in considerable detail in the recent Barton Springs Pool HCP that addresses the same Covered Species, and those descriptions are incorporated herein by reference (City of Austin, 2013); The Barton Springs Pool HCP can be accessed online at: http://www.austintexas.gov/watershed_protection/publications/document.cfm?id=203078. This section is based largely on those descriptions and highlights the aspects of the environmental setting that are most pertinent to the District’s Covered Activities, the Covered Species, and this HCP.

3.1.1.1 Physical Environment

The Planning Area is in the southern extension of the North American Great Plains, at the eastern edge of the large Edwards Plateau region in Central Texas. The Balcones Fault Zone straddles the boundary between the Edwards Plateau to the north and west and the Gulf Coastal Plain to the east and south. A number of large springs, including Barton Springs, are at land surface along the fault zone, where more permeable, older limestone layers are juxtaposed against less permeable younger layers. Barton Springs is located along and in Barton Creek, a major tributary just upstream from the Colorado River. Barton is the lowest in elevation of these springs, and it and the Colorado River form the regional flow boundary for deep, fresh groundwater that is not discharged at other, higher-elevation springs.



Basemap: Contributing Zone compiled from Onion Creek, Barton Creek, and Blanco River watersheds;
Recharge Zone extracted from TCEQ Edwards Aquifer Administrative Boundary dataset;
Confined Zone modified from TWDB Major Aquifers, Edwards Aquifer subcrop dataset;
Saline Zone extended from Edwards Aquifer subcrop eastern boundary.
Robin Gary, BSEACD, October 2013.

Figure 3-1: Planning Area of District Habitat Conservation Plan.
The Planning area comprises the areas shown in color. The District jurisdictional area and the ITP Area are coincident and comprise the area within the black boundary.

The climate of the Planning Area is classified as subtropical humid, with mild winters and hot summers. But during multi-year periods, the climate might be considered semi-arid, especially in western parts of the Hill Country. Heavy rainfall can occur in any month, but generally the winter months are drier and, at least statistically, the early- and late-summer months are wetter than average. Rainfall and runoff are highly variable in time and space. The concept of "average rainfall" is misleading when considered in a predictive sense at any one location, and there are significant gradients toward smaller rainfall and greater evapotranspiration from northeast to southwest across the Planning Area. Generally, annual evaporation exceeds annual rainfall considerably, often by a factor of two or more; the long-term average factor is about 1.6. Antecedent soil-moisture conditions determine whether and how much rainfall of a given duration is required to produce runoff to the local streams.

The entire area is prone to drought, which may be severe and persist for months to many years. Virtually every decade has had one or more significant drought periods that has lasted for a substantial part of a year or more. The most severe drought in recorded history in the area was the drought during 1950–57, which is designated for water planning purposes as the DOR. During that drought, Barton Springs had its lowest recorded daily flow, 9.6 cfs, and its lowest monthly flow, 11 cfs (See Section 3.2.2.1.2, Sources of Variation in springflow at Barton Springs). Conversely, the small streams in the Planning Area from time to time are subject to short-term, sometimes extreme flooding. Such flooding is associated with tropical moisture systems that move inland and meet the Balcones Escarpment and/or cold air masses, which produce flooding rainfall intensities. Floods may actually occur in the midst of a drought, and the storms that cause the floods may or may not relieve the drought, depending on location of the rainfall and persistence of the drought. During the decade that is designated by the TWDB as the DOR for this region, there were significant periods when streamflow and springflow were near average, at least for a while. These variations in rainfall and drought conditions appreciably affect the natural resilience and ecological health of creeks, rivers, and streams and their resident flora and fauna (Service, 2013b; Poff and Ward, 1989; Resh et al., 1988).

The Planning Area is drained by two major Texas river systems, with the Colorado River system tributaries in the northern part and the Guadalupe-Blanco River system tributaries (including the upper part of the main stem of the Blanco) in the southern part. All surface streams except the main river stems are non-perennial, although most have base flow (-sustained flow) that is supported by shallow groundwater contributions during non-drought and non-severe drought periods. Only the primary river systems have large enough catchment areas (drainage basins) to support reservoirs for water supply and/or downstream areas that justify flood-control impoundments. Areas distant from river main stems typically are dependent on wells and groundwater for reliable and economic water supplies; these include the more rural parts of the Planning Area.

3.1.1.2 Biological Environment

The Planning Area includes parts of two terrestrial biogeographically defined ecoregions, with the dissected margin of the Edwards Plateau ecoregion to the west and the southern part of the Texas Blackland Prairie ecoregion to the east (Texas Parks and Wildlife Department (TPWD), 2012). The rolling topography has level to gently rolling plains in the east and steeply sloping and dissected uplands in the west. In combination with climate gradients from east to west and different geology on either side of the Balcones Fault Zone, soil types with varying depths and textures have been produced, which in turn support diverse vegetation and wildlife.

The Blackland Prairie is a native prairie grassland community that is dominated by a diverse assortment of perennial and annual grasses. Its dark soil is considered some of the richest soil in the world and supports an active agricultural community, especially to the north of the Planning Area. This ecoregion predominately comprises live oak and Ashe juniper, with increasing amounts of post oak, blackjack oak, American elm, winged elm, cedar elm, sugarberry, green ash, osage-orange, honey mesquite, and eastern red cedar in the northeastern parts of the Planning Area. Pecan, black walnut, black willow, American sycamore, honey locust and bur oak commonly are in bottomland woodlands throughout this region (Texas Forest Service at Texas A&M University, 2008).

Common vegetation in the Planning Area (TPWD, 2013) includes:

Switchgrass	Bald cypress
Bluestem grass	Pecan
Grama grass	Possumhaw
Indiangrass	Smartweed
Wild rye	Sugarberry
Curly mesquite	Boxelder
Buffalograss	Buttonbush
Live oak	Black willow
Shinnery oak	Marsh purslane
Ashe juniper	Water pennywort
Mesquite	Cattail

Common wildlife in the Planning Area (TPWD, 2013) includes:

Muskrat	Northern mockingbird
White-tailed deer	Guadalupe bass
Rio Grande turkey	Salamanders
Raccoon	Cricket frog
Javelina	Gulf Coast toads
Brazilian freetail bat	Grebes
Ringtail	Blue herons
Nine-banded armadillo	Green-backed heron
Tarantula	Kingfishers

Both ecoregions are undergoing change as the human population increases. In some areas close to urban areas, suburbanization is replacing native vegetation with turf grasses, non-native plants, and impervious cover, and displacing native wildlife. But perhaps the most pervasive and ecologically significant long-term change for the non-suburbanizing part of the Planning Area is the purposeful suppression of wildfire. As noted in the Barton Springs Pool HCP (City of Austin, 2013):

> The natural vegetation of the Edwards Plateau uplands is characterized by oak savannas and grassy terrains, bisected by canyons and riparian areas with thick forest vegetation and a great diversity of trees and shrubs. The Blackland Prairie was dominated by tall-grass prairie and deciduous bottomland forest. The savanna and prairie ecosystems were maintained by fires and grazing bison. With the suppression of fire [as the area has developed], the openness once characterizing portions of these regions has been severely reduced. This allowed the encroachment and increase in abundance of species once controlled by fire, such as Ashe Juniper (*Juniperus ashei*). Natural savanna and tall-grass prairie are absent in much of both ecoregions today.

The springs along the margins of the Edwards Plateau have their own ecological character. The smaller, headwater seeps and springs tend to have shallow water, high canopy cover, fast current, and low nutrient content (City of Austin, 2013; Mabe, 2007). These factors likely result in naturally low abundance and diversity of aquatic macrophytes (visible plants) and macroalgae (multicellular algae). The COA notes that larger springs within wider, higher-order streams, such as the reach of Barton Creek that contains outlets of Barton Springs, likely have a greater abundance of aquatic macrophytes than headwater springs because the canopy cover is less, current is slower, and nutrient load is greater (City of Austin, 2013).

The fauna within the Planning Area are mostly transitional (Abell et al., 1999). Although the Edwards Plateau is home to more than 100 fish species, few of them are endemic (found only in a specific location). In contrast, many endemic aquatic fauna are in spring-fed streams of the Edwards Plateau. More information on the vegetation and fauna specifically associated with the Barton Springs complex is in Section 3.2.2.2, Ecological Setting.

A summary listing of the plant and animal species that the TPWD considers to be in greatest need of conservation is in Appendix A, with separate tables for the Edwards Plateau and Texas Blackland Prairie ecoregions. Federally protected species of potential interest specifically to this HCP also are identified and discussed as to their relationship to the proposed Covered Activities in Section 3.2.4, Protected Species in the ITP Area.

3.1.1.3 Man-made Environment

The Planning Area is on the suburban fringes of the Austin-San Marcos Metropolitan Statistical Area, which includes Austin, Buda, Kyle, and San Marcos, all of which are undergoing rapid growth that extends into the Planning Area. The current (2014) population of this area has been estimated by the District, on the basis of geospatial analysis of the latest census data, to be 583,000. It is expected to increase to more than 800,000 during the proposed 20-year term of the ITP, using conservative growth-rate projections in the ongoing regional water-resource planning by the TWDB:

Planning Horizon	Population in HCP Planning Area
2010 Census	525,000
2015 (Start of ITP)	583,000
2035 (End of ITP)	803,000
2040	855,000

The COA has indicated that much of the population increase in the Colorado River basin part of the Planning Area will occur in the Barton and Williamson Creek watersheds (City of Austin, 2013). Growth associated with the Cities of Kyle and San Marcos in the Planning Area will largely be in the Plum Creek and Blanco River watersheds of the Guadalupe-Blanco River basin. The more western and eastern parts of the Planning Area will continue to be mostly rural, although some areas near transportation corridors and communities outside of suburbs will increasingly become rural residential and commercial.

Much of the firm-yield water supply (water that will be physically available and that is authorized for use during all hydrologic conditions, including Extreme Drought) throughout the Planning Area is fully subscribed, including supplies of fresh groundwater from the Aquifer. For this reason, the accuracy and precision of future population estimates are not particularly germane to future demand for existing water supplies in the Planning Area. Public water-supply (PWS) systems are now actively pursuing alternative surface-water and groundwater supplies from outside the Planning Area to serve their projected growth. Consequently, the number of people who are now provided groundwater from the Aquifer is not expected to increase significantly from the current 70,000 estimate; in fact it may decrease as smaller PWS systems using the Aquifer are subsumed by and become part of larger PWS systems on alternative supplies.

The population growth that takes place in areas that are outside the various municipal limits will create wastewater treatment and disposal challenges that may have adverse effects on water quality. Increasing use of centralized wastewater treatment systems that directly discharge even highly treated wastewater into small streams upstream from the Recharge Zone is likely, along with continued proliferation elsewhere of land-application systems and septic tanks. These facilities have the potential for surface-water and groundwater quality degradation if they are not adequately sited, designed, and/or maintained.

3.1.2 Hydrogeologic Framework of Planning Area

An understanding of the hydrogeologic framework supports the District HCP. The detail provided in this subsection is required to establish and monitor effectiveness of suitable conservation measures for the Covered Species.

The only recognized, known habitats for the Covered Species are the four Barton Springs outlets[4] (the multiple sub-outlets of Main Springs [Parthenia Spring] in Barton Springs Pool, Eliza (Concession) Spring, Old Mill [Sunken Garden, or Zenobia] Spring, and Upper Barton Spring); their associated surface spring runs; and the subterranean (underground) areas of the Barton Springs complex (Figure 3-4). These outlets are the primary points of freshwater discharge from the Aquifer. So water passing into and through Barton Springs comes primarily from the Aquifer, although also occasionally and transiently from a flooding Barton Creek.

The Aquifer is a karst aquifer, characterized by features such as caves, sinkholes, sinking streams (streams that lose water to an aquifer), springs, and other conduits that have been enlarged by dissolution of the host carbonate rock (Woodruff and Abbott, 1979). The Aquifer also is in an area with extensive, complex faulting and fracturing, which provide the potential for additional hydrologic interconnections.

3.1.2.1 Aquifers and Hydrozones

The near-surface hydrogeology of the Planning Area is dominated by two karst aquifers associated with the Balcones Fault Zone, the Edwards Aquifer and the Trinity Aquifer. These aquifers, although primarily the Edwards, are central to the need for and development of the HCP.

The Edwards Aquifer is composed of Cretaceous-age limestones and dolomites of the Edwards Group (Rose, 1972). At the regional level, the Edwards Aquifer has three segments, commonly

[4] Throughout this HCP, the District designates the specific outlets of the Barton Springs complex by the following names: Main Springs (which in this HCP actually refers to closely associated, multiple sub-outlets within Barton Springs Pool), Eliza Spring, Old Mill Spring, and Upper Barton Spring. All of these have alternative names, shown here in parentheses, which are sometimes used by various other entities. There is no standard usage.

referred to as the San Antonio (or Southern) segment, the Barton Springs segment, and the Northern segment. The San Antonio segment and the Barton Springs segment are separated by a groundwater divide, and the Barton Springs segment and the Northern segment are separated by the Colorado River (Figure 3-2). The freshwater part of the Barton Springs segment that contributes to the habitat for the Covered Species covers about 170 square miles (440 square km) (Slade et al., 1986). The hydrologic region that influences the Aquifer and therefore the District HCP (Planning Area, Figure 3-1), comprises the Aquifer's Contributing Zone, Recharge Zone, Confined Zone, and Saline Zone in Central Texas. Most of the HCP Planning Area is in northern Hays and southern Travis Counties. Smaller parts of the Planning Area extend into Bastrop, Blanco, Caldwell, Comal, and Kendall Counties.

The freshwater part of the Barton Springs segment consists of two major zones: (1) the Recharge Zone, where rocks of the Aquifer are exposed and hydrologically unconfined[5]; and (2) the Confined Zone, where the Aquifer is overlain by other rock units (such as clay) and generally is hydrologically confined. There is a transitional area between the two zones where the hydrologic conditions (confined vs unconfined) can vary depending drought or non-drought conditions (Slade et al., 1986).

The Recharge Zone as defined herein covers about 107 square miles (277 square km) of the Planning Area (Figure 3-1). Recharge is the process by which water enters and replenishes an aquifer. Most recharge to the Aquifer is derived from streams originating in the Contributing Zone, up gradient and generally west of the Recharge Zone. Water flowing onto the Recharge Zone sinks into numerous caves, sinkholes, and fractures along numerous (ephemeral [briefly flowing] to intermittent [periodically flowing]) streams (Slade et al., 1986). For the Barton Springs segment, Slade (2014) estimated that as much as 75% of recharge to the aquifer is from water flowing in these streams. The remaining recharge (25%) occurs as infiltration through soils or direct flow into discrete recharge features in the upland areas of the Recharge Zone (Slade, 2014). However, a more recent study by Hauwert (2009, 2011) indicates that upland recharge may constitute a larger fraction of total recharge than stated in Slade (2014). Hauwert and Sharp (2014) state that recharge in the uplands is 31% of rainfall. Both studies recognize that a significant amount of recharge to the Edwards Aquifer is from flow in the creeks that cross the Recharge Zone. Additional potential sources of inflows and recharge to the Aquifer are discussed in section 3.2.2.1.2 Sources and Implications of Variation in Springflow at Barton Springs.

Mean surface recharge to the Barton Springs segment of the Edwards Aquifer should be approximately equivalent to the more directly measured mean flow, or about 53 cfs for the period of record (1.5 m^3/s; Scanlon et al., 2001). Climatic changes since the 1960s indicate the mean flows are about 65 cfs (1.8 m^3/s; Hunt et al., 2012b), and even higher if you consider total discharge (which includes pumping). Recharge is highly variable in space and time and focused within discrete features (Smith et al., 2001). It is estimated that maximum recharge during flooding may approach 400 cfs (11 m^3/s) (Slade et al., 1986). For example, Onion Creek is the largest contributor of recharge to the Barton Springs segment (34% of total creek recharge) with

[5] Unconfined aquifers or zones are not overlain by relatively impermeable rock unit(s). Water levels in tightly cased wells in unconfined units are below the top of the aquifer or hydrozone (unless the land surface is flooded). Confined aquifers or zones are overlain by relatively impermeable rock unit(s). Water levels in tightly cased wells in confined units are above the top of the aquifer or zone and are above land surface where springs flow.

maximum recharge as much as 160 cfs (4.5 m^3/s) (Slade et al., 1986). Antioch Cave, which is in the Onion Creek channel, is the largest-capacity discrete recharge feature known in the Barton Springs segment, with an average recharge of 46 cfs (1.3 m^3/s) and a maximum of 95 cfs (2.7 m^3/s) during a 100-day period (Fieseler, 1998). A more recent study (Smith et al., 2011) estimates that Antioch Cave is capable of recharging as much as 100 cfs (2.8 m^3/s) and that the recharge part of Onion Creek upstream from Antioch Cave is capable of recharging about 100 cfs (2.8 m^3/s). The District has constructed, and operates under an Environmental Protection Agency grant program, a recharge enhancement facility at Antioch Cave to preserve and increase recharge to the Aquifer derived from this discrete feature. The District is modified

Protection from adverse effects of storm runoff and conservation of streamflow in the watersheds of these creeks are important to maintaining the water quality and chemistry of the habitat at Barton Springs (Service, 2005). The Recharge Zone has numerous wells, many of them low-capacity individual household supply (domestic-use) wells and also a few large-capacity wells, especially where the saturated thickness of the Aquifer is relatively large and is able to supply relatively large amounts of water without being overly susceptible to drought impacts.

The Confined Zone generally is fully saturated. This 59-square-mile (153-square-km) area is where most groundwater withdrawal occurs (Figure 3-1). The Confined Zone comprises a continually confined part, which is farther from the Recharge Zone and always confined, and an intermediately confined, transitional part closer to the Recharge Zone that varies between unconfined and confined conditions, depending on water levels in the Aquifer. Some areas immediately east of the Recharge Zone are unsaturated to variable depths below the overlying low-permeability units. In the Confined Zone, dipping and faulted impermeable layers of clay and other less-permeable rocks overlie the Aquifer, which becomes progressively deeper with distance eastward. Aquifer conditions in the Confined Zone thus transition from intermediately confined to continually confined with distance eastward. Because much of the water moving through the Aquifer is under pressure in dissolution cavities and conduits that transport water from higher elevations, areas of the Aquifer near springs show both unconfined and confined characteristics, depending on water levels in the Aquifer[6] (Wong et al., 2012). Accordingly, the Barton Springs complex can be considered a hybrid (gravity and artesian) spring complex.

Upstream from the Aquifer is the Contributing Zone, which contributes surface runoff and base flow of streams to the Aquifer but is not considered a part of the Aquifer (Figure 3-1). The Contributing Zone spans about 671 square miles (1,738 square km) of the Planning Area and includes parts of Travis, Hays, Blanco, Kendall, and Comal Counties. What has been historically designated as the Contributing Zone during all hydrologic conditions encompasses the upper watersheds of the six major creeks that cross the Recharge Zone. However, this definition excludes the upper Blanco River watershed that recent studies (Smith et al., 2012a; Casteel et al., 2012; Smith et al., 2014) have shown to be a contributor of recharge to the Aquifer during drought conditions. Although the six creeks in this area are the source for most of the water that enters the aquifer as recharge, the Blanco River is an important contributor during severe drought conditions. The Recharge and Contributing Zones together make up the total area that provides meteoric water (water that is derived from relatively recent precipitation on

[6]"Unconfined characteristics" implies water levels in the Aquifer are below the top of the aquifer. "Confined characteristics" implies water levels in the Aquifer are above the top of the aquifer. At spring outlets, the elevation of land surface is below the elevation of the water level in the Aquifer, hence water flows from the outlet.

land surface) to the Aquifer.

The eastern boundary of the Aquifer is the interface between the freshwater zone and the Saline Zone (sometimes referred to as the “bad-water” zone) of the aquifer, characterized by a sharp increase in dissolved constituents (more than 1,000 mg/L total dissolved solids [TDS]) and a decrease in permeability (Flores, 1990). The Saline Zone has groundwater that ranges from brackish (greater than 1,000 mg/L TDS) to saline (greater than 10,000 mg/L TDS). Hunt et al., (2014) provides a delineation of the boundary for the planning area based on new groundwater chemistry data. The report summarizes many previous studies and concludes that the interface appears to be relatively stable over time in the Barton Springs segment of the Edwards Aquifer. Although encroachment does not appear to be a threat to freshwater supplies, changes in the springflow chemistry at Barton Springs suggest some leakage (flow) into the freshwater aquifer under drought conditions (Hunt et al., 2014).

The Trinity Aquifer underlies the Recharge, Confined, and Saline Zones of the Aquifer. The Trinity Aquifer is also a karst aquifer but with much more variable yield (in this context, the limiting rate at which groundwater is capable of entering a well bore) and water chemistry than the Edwards Aquifer, owing to its rock characteristics. The Trinity Aquifer crops out across the entire Contributing Zone and provides base flow to the larger streams there that eventually recharge the Edwards. In addition, the uppermost part of the Trinity Aquifer and the Edwards Aquifer are hydrologically connected (allows exchange of water between units) (Wong et al., 2014), and in some places the Trinity probably contributes flow to the Edwards and vice versa, depending on their respective water-level elevations. Recent studies (Wong et al., 2014; Smith and Hunt, 2011) have shown that the Edwards Aquifer is not hydrologically connected to the deeper units of the Trinity Aquifer.

3.1.2.2 Groundwater Flow Conditions

In the Recharge Zone, meteoric water moves vertically from the land surface into the Aquifer through faults, fractures, and dissolution features in streambeds and less dominantly via soil infiltration in the karstic uplands. After reaching the water table, it then moves more laterally through the Aquifer via groundwater flow paths inside caverns, conduits, and other dissolution features that differ in size. Groundwater movement in the western part of the Aquifer is generally to the east and then north (Figure 3-2). Groundwater levels throughout the Aquifer are highly interrelated and, in many areas, correlate well with springflow at Barton Springs (Smith and Hunt, 2004).

Runoff flowing across the Recharge Zone and entering the Aquifer reaches the water table quickly. And groundwater flow velocities in the Aquifer are very rapid (Hauwert, 2009; Hauwert et al., 2004; BSEACD, 2003). Groundwater-tracing studies have delineated several major groundwater flow routes and have been used to measure groundwater velocities. The major flow routes transmit water derived from different contributing sources, including relatively new recharge, water moving into and out of storage, older recharge from areas distant from Barton Springs, and interformational flow (flow between geologic units, or formations) of differing characteristics, including the saline part of the Edwards (Mahler and Bourgeais, 2013; Johns, 2006). The flow rates of groundwater along the dominant flow paths range from about 1 mile (1.6 km) per day under low groundwater flow conditions to about 5 miles (8 km) per day under moderate to high groundwater flow conditions (BSEACD, 2003). The rapid hydrologic response of the Aquifer to precipitation and surface runoff emphasizes the importance of protecting the quality and quantity of water in each of the six major creeks, and the Blanco River, in conserving the habitats of the Covered Species (Johns, 2006; Service, 2005; Hauwert et al., 2004).

The rate at which groundwater discharges at Barton Springs[7] depends directly on water levels in the Aquifer. Under drought conditions, surface flow in the Contributing Zone creeks ceases, and Aquifer water levels decrease as water is discharged from the Aquifer at pumping wells and spring outlets. Flow from small spring outlets at relatively high elevations, such as Upper Barton Spring ceases for extended periods, and flow from the main outlets decreases. At low water levels in the Aquifer, less groundwater flows solely (although rapidly) through large conduits.

In the immediate vicinity of the Aquifer's major discharge at Barton Springs, periods of high and low flow have been a natural characteristic of the Barton Springs/Barton Creek ecosystem (City of Austin, 2013, 2007a, 2007b, 2006, 1997). Presently, the dam and other constructed infrastructure creating Barton Springs Pool inhibit the beneficial flushing of sediment and debris provided by shallow, free-flowing water from the spring outlets and the creek. For a given flow, shallow streams and creeks have greater flow velocities and consequently, stronger natural cleansing power. In addition, disturbance by episodic flooding is an important feature of streams and rivers (Gordon et al., 2004 and references therein; Poff and Ward, 1989; Resh et al., 1988) and was a natural characteristic of the Barton Springs complex before alteration by humans beginning in the late 1800s. The District has no authority or control over the physical conditions and maintenance of the surface-water system that could affect the creeks and spring outlets.

Dye-tracing studies (BSEACD, 2003; Hauwert et al., 2004), direct flow measurements of the individual outlets that are statistically correlated with combined spring flow (City of Austin, 2013), and outcomes of human-controlled, pool-drawdown events have shown that the spring outlets of Barton Springs are hydrologically related, particularly Main Springs and Eliza Spring. These analyses indicate that any factor that causes a change in water quantity at one spring outlet also has the ability to affect water quantity at the other spring outlets at Barton Springs (Service, 2005).

[7]Rates of streamflow and springflow are conventionally expressed as cubic feet per second, or "cfs." Rates of groundwater use and overall production from an aquifer are usually expressed in acre-feet (AF) per unit time, typically per year. Groundwater withdrawal from individual wells is usually expressed in gallons per minute or thousand gallons per day. The District's permits are issued in terms of gallons per year. To facilitate comparisons of discharges from wells and springs, the District uses "cfs" for both in this HCP. 1.00 cfs = 723 AF per year. 1000.0 AF per year = 325.9 million gallons per year = 892,700 gallons per day.

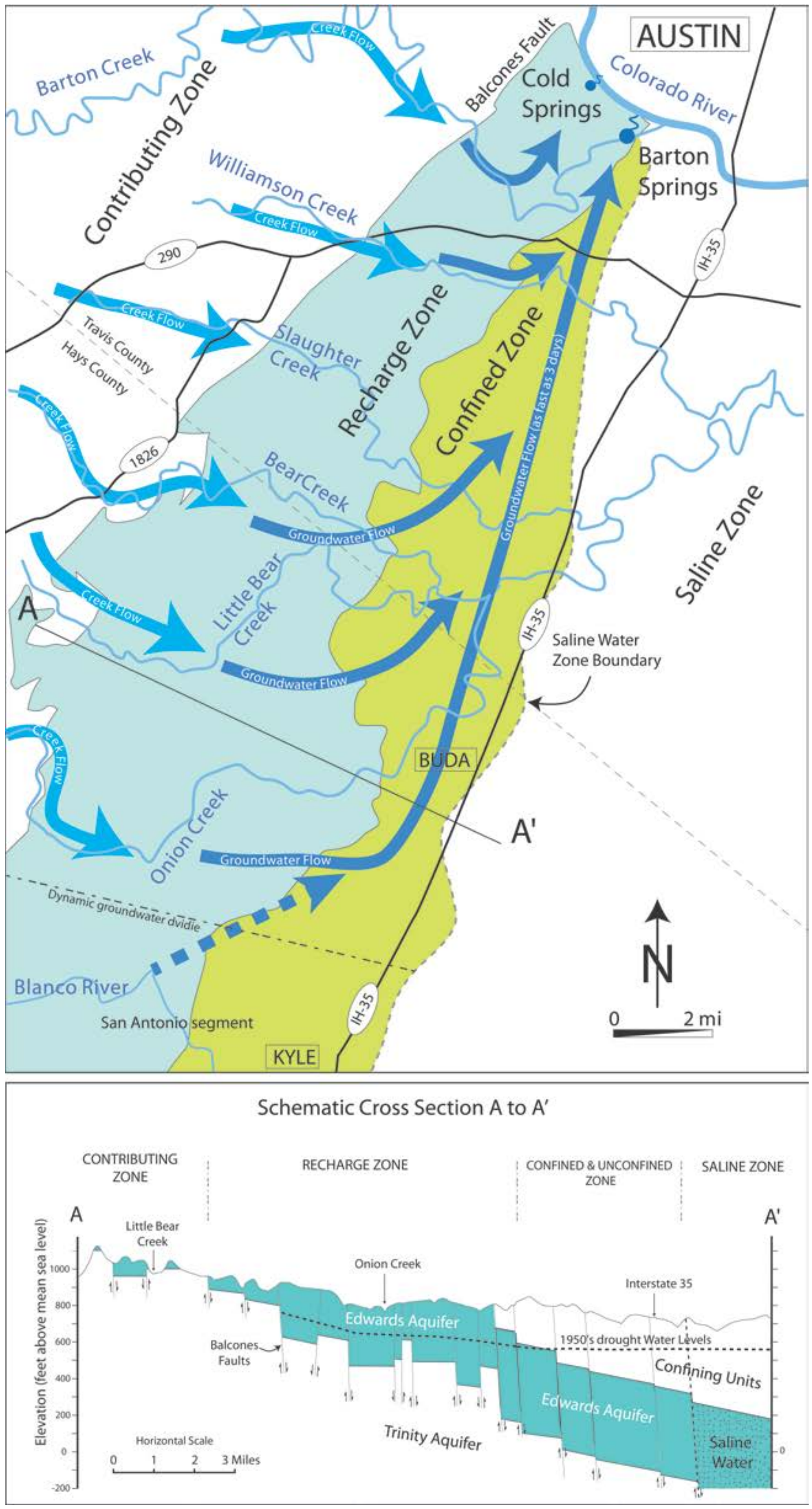


Figure 3-2: Conceptual Hydrology of the Barton Springs segment of the Edwards Aquifer. Groundwater flow paths and approximate location of the hydrologic divide that separates the San Antonio segment from the Barton Springs segment of the Aquifer are shown. The Colorado River separates the Barton Springs segment from the Northern segment of the Aquifer. (Source: Adapted by BSEACD from figure in Smith and Hunt, 2004).

3.1.3 Barton Springs/Edwards Aquifer Conservation District Jurisdictional Area

The District's jurisdictional area, bounded in black in Figure 3-1, is shown in more detail in Figure 3-3. This area, which comprises about 255 square miles in northwestern Caldwell, northeastern Hays, and southeastern Travis Counties, is statutorily established and delineates the area where the District's rules and regulations are enforceable. The boundary of this area approximates the hydrogeologic boundaries of the Aquifer in places, and in others, follows certain boundaries of the service areas of several public water-supply utilities as they existed when the District was formed in 1987.

Under its enabling legislation, the District's jurisdiction is defined by metes and bounds (system of describing land using physical features, directions, and distances) to approximate a combination of natural and man-made boundaries. On the west, the boundary was drawn to approximate the location of the western edge of the Edwards Aquifer outcrop, and on the north by the Colorado River. The eastern boundary is generally formed by what were the easternmost service area limits, at the time the District was formed in 1987, of what are now the Creedmoor-Maha Water Supply Corporation, Monarch Utilities/Southwest Water Company, and Goforth Special Utility District. Changes made in those other entities' boundaries since then have not changed the District's boundaries. (In 2009 the District legislatively de-annexed a small part of the service area of one of these utilities in Bastrop County, which is now outside the District.) The District's southwestern and southern boundary is generally established in alignment with the approximate average position of the groundwater divide between the Barton Springs and the San Antonio segments of the Edwards Aquifer (Figure 3-2). To the southeast, the boundary is along the southernmost service-area boundaries of several water-supply utilities, including Goforth (the District permittee with the largest authorized use, at 351 million gallons per year) and Monarch Utilities, another large Aquifer user. So, by original design, the District's jurisdictional boundaries have been aligned with the area where the Aquifer is used as a water supply.

Some of the Aquifer water withdrawn within the District is physically transported by pipeline to other parts of the District and to nearby areas outside the District. The native groundwater (water that occurs naturally within an aquifer without influence from pumping or other anthropogenic [human-caused] activities) in the eastern part of the District's jurisdiction is brackish to saline, and therefore it is generally unsuitable as a potable water supply without expensive treatment. Freshwater supplies to this area are provided by Edwards wells west of Interstate Highway 35 and transported to customers of those water utilities by various water suppliers that are District permittees. (Other water sources also supply this area.) Also, a single well in the extreme southern part of the District's jurisdiction is the most prolific well in the District, providing a large amount of water that is exported from the District to the City of Kyle, just outside the District's jurisdictional boundary. However, the well is within the District, and thus Kyle is one the District's largest permittees (350 million gallons per year).

The District regulates groundwater from all aquifers underlying its jurisdictional area. An increasing amount of groundwater from the Trinity Aquifer, especially the middle and lower zones of the Trinity Aquifer (commonly called the Middle and Lower Trinity Aquifers, respectively), is now being used in the jurisdictional area as an alternative supply to the Edwards and is also managed by the District.

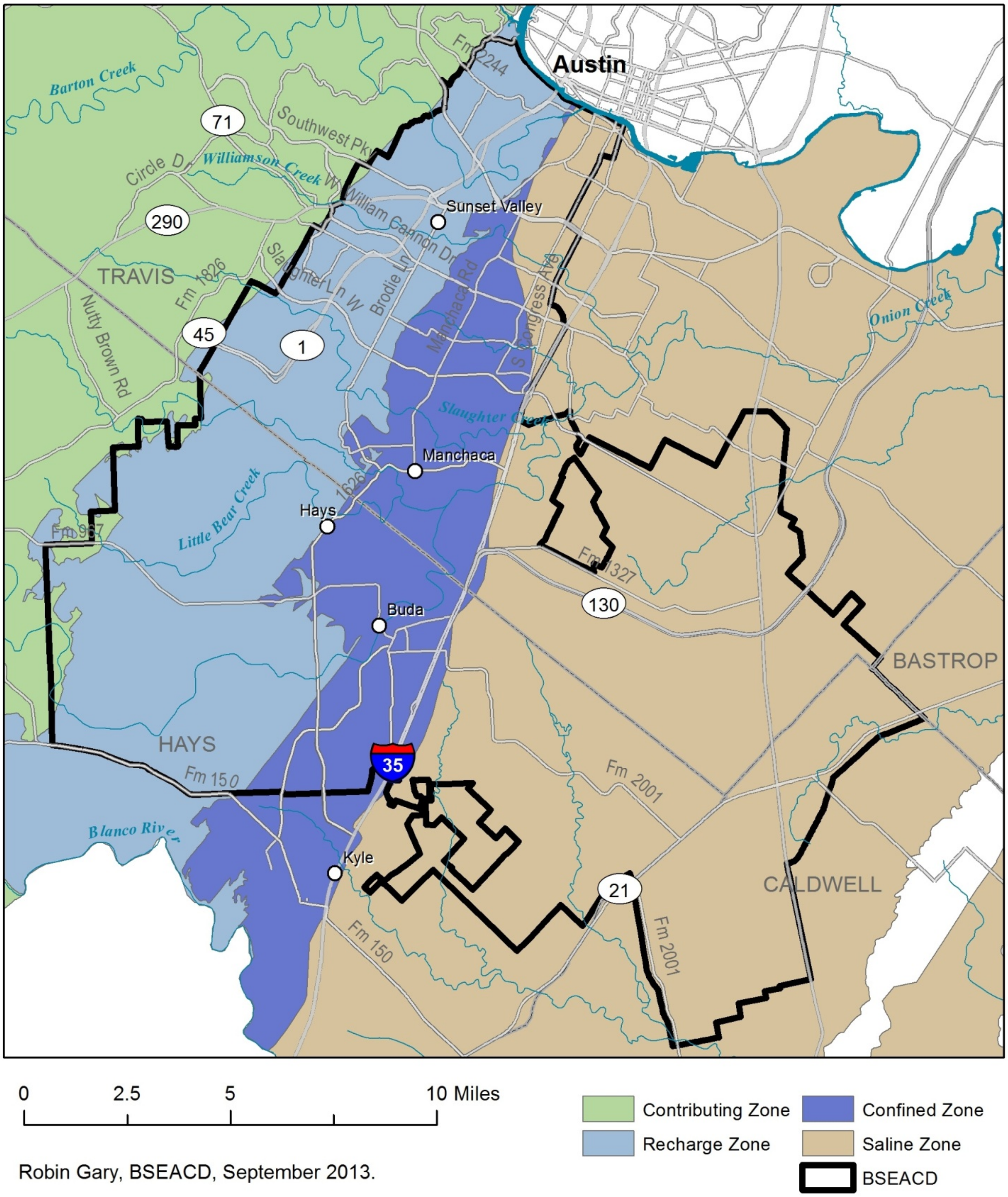


Figure 3-3: Barton Springs/Edwards Aquifer Conservation District Jurisdictional Area.
The area is coincident with the ITP Area. Source: BSEACD (2013)**.**

3.2 Incidental Take Permit Area

The ITP Area comprises (a) the subsurface part of the District's jurisdictional area, and (b) the spring outlets area, specifically the surface and subsurface areas in the immediate vicinity of the natural outlets of the Aquifer at Barton Springs. The ITP Area defines where the Covered Activities are authorized under the ITP and where conservation measures are to be implemented.

3.2.1 Subsurface Part of District's Jurisdictional Area

The subsurface part of District's jurisdictional area (Figures 3-1, Figure 3-3) is hydrogeologically and geographically the ITP Area; and both are part of the Planning Area. The subsurface part of the jurisdictional area, described in Section 3.1.2, Hydrogeologic Framework of the Planning Area, is composed of the Aquifer and its groundwater flow system that provides water to Barton Springs. It is within the District's jurisdictional area that its rules and regulations for groundwater management apply.

The Edwards Aquifer in the southernmost part of the Planning Area (parts of the Recharge Zone and Confined Zone outside the District's jurisdictional area in Figure 3-1), is regulated by the Edwards Aquifer Authority (EAA) in San Antonio. The subsurface part of the aquifer in this area is not included in the District's jurisdictional area or ITP Area. It is included in EAA's HCP (Edwards Aquifer Recovery Implementation Plan) and ITP Area (EARIP, 2012).

3.2.2 Spring Outlets Area

3.2.2.1 Physical Setting

3.2.2.1.1 Physical Characteristics of Barton Springs

The ITP Area includes the submerged surface rocks and underlying shallow subsurface rocks in the immediate vicinity of the individual springs that together constitute the Barton Springs complex. The complex comprises Main Springs, which is impounded to form Barton Springs Pool; Upper Barton Spring; Eliza Spring; and Old Mill Spring (Figure 3-4). Any incidental take of Covered Species would be expected to occur in the submerged areas in, below, or just beyond the individual spring outlets, which are the primary natural discharge points of the Aquifer and the only known habitats of the Covered Species. The black line in Figure 3-4 circumscribing the outlets illustrates the inferred area of potential surface and subterranean habitat and subterranean migration zones for the Barton Springs salamander; and the area within the black line is the ITP Area for the Barton Springs Pool HCP. The larger area enclosed by the red line is the Service's designated Critical Habitat for the Austin blind salamander (Service, 2013a). The yellow lines represent the perimeters of protected salamander habitat at each spring site. Currently (2014), the surface outflow stream from Eliza Spring is contained within a buried pipe, which has until now carried water from Eliza in the subsurface directly into the Barton Springs Pool bypass culvert; but it is to be restored ("daylighted") by the COA in 2015.

The localized part of the District ITP Area that encompasses the spring outlets is thus in the Barton Springs Pool ITP Area. While the District HCP covers the same Covered Species as the Barton Springs Pool HCP, the Barton Springs Pool HCP covers impacts by recreational use (swimming, diving, wading) and maintenance operations (cleaning, caretaking) of the Pool and work in the spring outlet areas, including areas of surface flow from the outlets. A detailed description of the habitats at the spring outlets is excerpted from the Barton Springs Pool HCP and provided as Appendix C. The COA owns the land where the individual spring outlets are, and under its HCP, maintains and operates all man-made structural elements around the spring outlets, including the Barton Springs Pool dam, impoundment, and bypass culvert. The District does not control access to or operate and maintain any part of the infrastructure at Barton Springs. Its groundwater management activities only affect, within limits, the amount of water issuing from the spring outlets and the chemistry of that water as related to and affected by the rate of discharge.

3.2.2.1.2 Sources and Implications of Variation in Springflow at Barton Springs

The primary threat to the Covered Species and their ecosystems—habitat changes accompanying low springflow—is affected by the District's Covered Activities during drought conditions in the Aquifer and at Barton Springs (Service, 2013b). Variable springflow conditions are the norm, for which the Covered Species appear to be well suited. Cleaveland (2006) concludes on the basis of regional dendrochronological (tree-ring dating) studies that droughts substantially more severe and prolonged than the drought of the 1950s have been a part of the prehistorical record. But increasing frequency of severe droughts and flash floods also appear to be the "new normal" (IPCC, 2013), which will continue to challenge and stress salamander populations.

The long-term (1917–2000) mean springflows at Barton Springs outlets, based on U.S. Geological Survey (USGS) data for combined springflows from the Barton Springs complex (Main Springs within the Pool, Eliza Spring, and Old Mill Spring; Upper Barton Spring is not included in these flows) was 53 cfs (Scanlon et al., 2001). In the more recent period since 1960, the mean springflow was 65 cfs (Hunt et al., 2012b). However, springflow has varied by nearly 17-fold from extreme low-flow to extreme high-flow conditions. The lowest daily flow recorded at Barton Springs was about 10 cfs during the record drought in the 1950s (Smith and Hunt 2004), and the highest-recorded daily mean flow was 166 cfs (Slade et al., 1986). The lowest daily mean value of the recent severe drought of 2008–09 was about 13 cfs on July 21, 2009 (U.S. Geological Survey, 2010). The more recent 2011 and 2013 severe droughts caused lowest daily mean flows of about 16 to 17 cfs. There is considerable uncertainty (as much as ±3 to 4 cfs) in measuring very low flows owing to the measurement approaches and tools available (Hunt et al., 2012a).

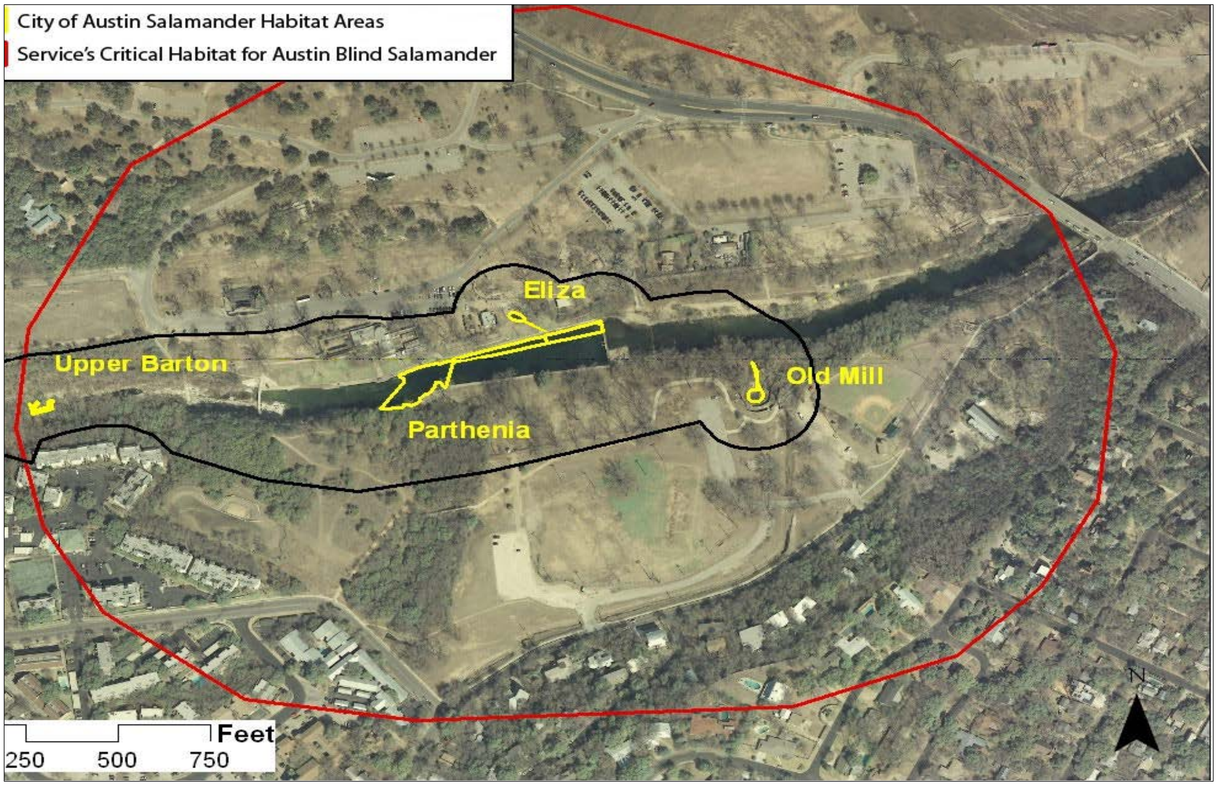


Figure 3-4: Incidental Take Permit Area of the Barton Springs Pool Habitat Conservation Plan. The area within the black line is the ITP Area for the Barton Springs Pool HCP. Note that Parthenia is also known as Main Spring. Source: City of Austin (2013)

Pumping from the Aquifer does not cause the wide variation in springflow; such variation is natural. This is illustrated by Figure 3-5, which is a "synthetic" hydrograph of springflow at Barton Springs; that is, springflow that would have existed naturally, without any pumping from the Aquifer, for the period of historical record, 1917–2013. This synthetic hydrograph was constructed using measured (for later parts of the period) and inferred (for certain earlier parts of the period) monthly springflow and pumpage data. Statistical analysis of the hydrograph, after conversion to a nonexceedance frequency distribution (graph that shows the percentage of time, or probability, that a given springflow is not exceeded), yields the relationships shown in Table 3-1. Table 3-1 shows the percentage of time that several springflows of importance to drought management (discussed further in Section 4.1.2, Historical Perspective of Covered Activities), under a condition of no pumpage, would not be exceeded.

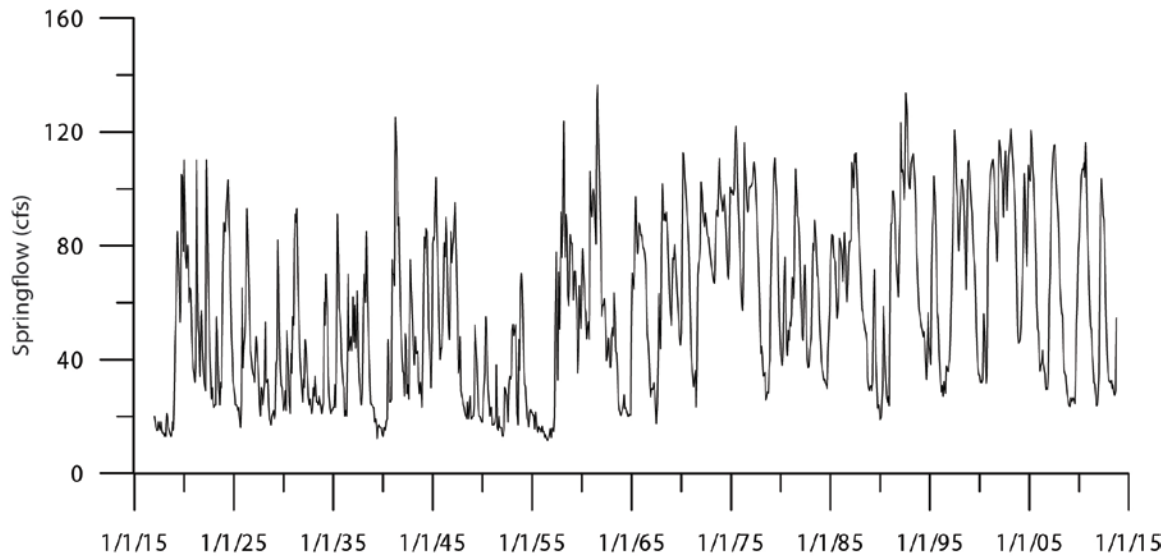


Figure 3-5: Reconstructed Barton Springs flow under a condition of no pumpage, 1917–2013. Springflow reflects the many wet and dry periods in the Planning Area over the period of record, which cause springflow to typically be above or below its long-term average of 53 cfs. The populations of the Covered Species have evolved and adapted to these natural fluctuations in flow and accompanying changes in water chemistry.

Table 3-1: Recurrence (nonexceedance) frequencies of natural (no Aquifer pumpage) springflow for specified drought management thresholds.
Frequencies are based on the 1917–2013 period of record, and the thresholds are those currently (2014) used by the District for managing groundwater.

Aquifer Condition	Total Flow at Barton Springs (cfs)	Percentage of Time Flow Not Exceeded
Average Flow	53	52
Stage II –Alarm Drought	38	36
Stage III – Critical Drought	20	9
Stage IV – Exceptional Drought	14	2
Emergency Response Period	10	<0.01
Regulated Minimum*	6.5**	0
No Springflow	0**	0

* Desired Future Condition, refer to Section 4.1.2, Historical Perspective of Covered Activities.
** Never observed in recorded history.

This analysis shows that even without any nonexempt pumping (pumping subject to the District's permitting program), the Aquifer would be in a District-declared groundwater drought status, designated by the onset of Stage II-Alarm Drought, more than one-third (36%) of the time, and in a Stage III-Critical Drought almost 10% of the time. The computed frequencies for these threshold flows, called recurrence or nonexceedance frequencies (percentage of time flow is below a designated rate), are calculated using monthly data, as pumping records used to construct the hydrograph are not reported on a more frequent basis. The recurrence frequencies thus correspond to springflow expressed as a monthly mean (monthly flow duration), and daily mean or instantaneous springflow will be somewhat larger or smaller. But during a prolonged, severe drought , with no stormflow, the natural flow of Barton Springs changes very slowly day to day and week to week (Smith and Hunt, 2004). Accordingly, the recurrence frequencies for monthly mean flows would be very similar to those for weekly mean or even daily mean flows during such times. Further, any differences actually observed between monthly and weekly or monthly and daily flow durations would be expected to decrease the percentage of time flow is below a designated rate for the smaller durations, as the changes would be derived from storms that would increase springflow rather than decrease it.

Flow at Barton Springs decreases as aquifer water levels decrease and the amount of groundwater in storage in the Aquifer decreases. Large decreases in water levels and storage generally have been caused by climate-related, prolonged periods of rainfall deficit rather than groundwater withdrawal. Such periods reduce the amount of water recharging the aquifer for extended periods of time. This is illustrated by the recent, multi-year hydrograph for Barton Springs flow in Figure 3-6, where the range in springflow in any one drought cycle (about 100 cfs) is roughly an order of magnitude larger than the amount of groundwater withdrawn during those times (about 10 cfs).

However, increased groundwater withdrawal will reduce the quantity of water in the aquifer and therefore springflow (Scanlon et al., 2001; Smith and Hunt, 2004). More than 1,200 active wells supply water for public, domestic, industrial, commercial, irrigation, recreational, and agricultural uses (Hunt et al., 2006). As described in more detail in Section 4.1.1, The Regulated Groundwater Community, only about 10% of these wells are regulated; but those regulated wells account for about 96% of the total volume of water withdrawn from the Aquifer (Smith et al., 2013; Smith and Hunt, 2004).

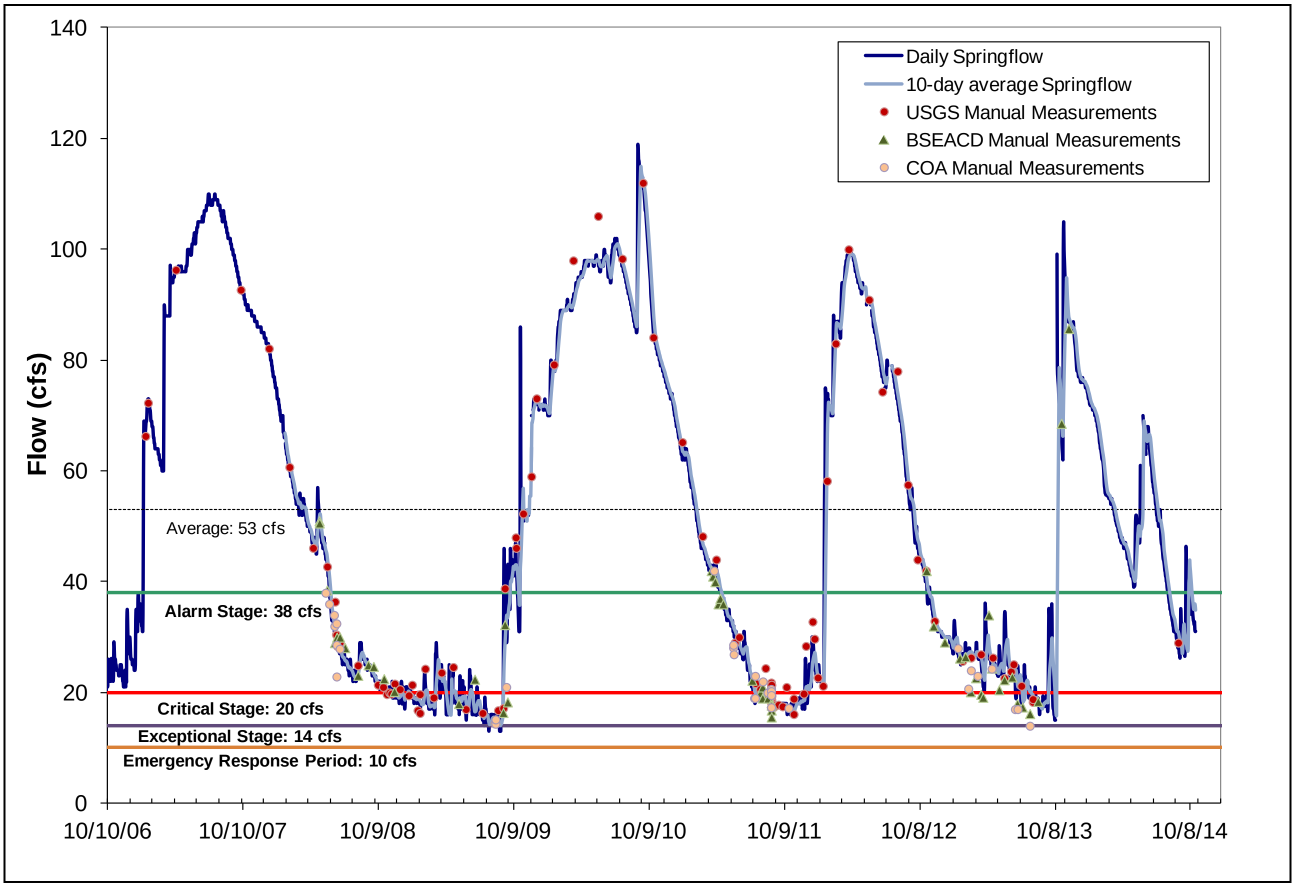


Figure 3-6: Variable flow at Barton Springs, September 2006–October 2014.
Drought stage thresholds that have groundwater management significance are indicated. Source: BSEACD.

It is important to consider how future groundwater withdrawals will cause variations in springflow, especially during future droughts. Groundwater flow modeling by Scanlon et al. (2001) indicated springflow at Barton Springs could possibly cease as pumping in the Aquifer reaches about 10 cfs. In 2004, the BSEACD did additional modeling to estimate the "sustainable yield" of water in the Barton Springs segment of the Aquifer based specifically on the possible recurrence of the DOR (Smith and Hunt, 2004, included herein as Appendix B). The BSEACD defined sustainable yield then as:

> "the amount of water that can be pumped for beneficial use from the aquifer under drought-of-record conditions after considering adequate water levels in water-supply wells and degradation of water quality that could result from low water levels and low spring discharge" (Smith and Hunt, 2004).

In that study, the BSEACD recalibrated the model used by Scanlon et al. (2001) to more accurately predict springflow and water level declines under DOR conditions. Withdrawals were projected for future years. This first-ever, rigorous assessment of the sustainable yield of the Aquifer (Sustainable Yield Study) showed that the then-authorized pumpage of the Aquifer, about 10.2 cfs, equivalent to 2.41 billion gallons per year, was essentially its sustainable yield, as that level of pumping during a recurrence of the DOR, *if un-curtailed*, would reduce springflow at Barton Springs to less than 1 cfs and would cause some 19% of the wells in the shallower part of the

Aquifer to have substantial yield problems from declining water levels in wells. More specifically, the recalibrated model indicated that under DOR conditions, the then-current pumpage of about 10.2 cfs would result in a monthly mean springflow of about 1 cfs for about 1 month. It also indicated that under continuous DOR conditions, projected withdrawals of 15 cfs, *if un-curtailed,* would cause Barton Springs to cease flowing for at least 4 months (Smith and Hunt, 2004).

The Sustainable Yield Study was the impetus for rulemaking that established the District's conditional-use (interruptible-supply) permitting program for Aquifer permit applications initiated after September 2004. This study also demonstrated the one-to-one correspondence between changes in pumped volumes and changes in springflow during Extreme Drought conditions (Smith and Hunt, 2004). Taken together, these findings ultimately formed the basis of the groundwater availability modeling for establishing modeled available groundwater (MAG) amounts related to the adopted Extreme Drought Desired Future Condition (DFC) of the Aquifer, which balances maintaining ecological habitat and well yields with being able to enforce as stringent curtailments as practicably possible.

At the time of the Sustainable Yield Study, the biological needs of the Covered Species were not explicitly and quantitatively addressed, other than the general recognition that nearly total cessation of springflow was not acceptable on ecological grounds. But the results of the numerical simulations had considerable implications for the Covered Species and their habitat. They suggested that, if Central Texas again experiences drought conditions similar to those of the 1950s, without active groundwater management, the viability of the species could be imperiled by critically low or no flow at spring outlets. In that circumstance, low flow at Barton Springs could cause substantial habitat degradation and a loss of plant and animal life (City of Austin, 2013). These effects and their consequences are characterized in more detail in Section 5.2.4, Effects of Take on Covered Species.

Numerous effects of low flow have been observed in various parts of the Barton Springs complex (City of Austin, 2013). Upper Barton Spring ceases to flow when the combined discharge from the Barton Springs complex is about 40 cfs. Old Mill Spring experiences a relatively sharp decrease in DO concentration at about 20 cfs combined springflow and ultimately a virtual cessation of flow at lower flow (about 14 cfs) (City of Austin, 2013; Turner, 2004b). Also, the COA discovered that Eliza Spring ceases to flow when the dam gates in Barton Springs Pool are opened and water is drawn down during periods of low springflow, which previously stranded and killed some salamanders. To prevent Eliza Spring from going dry while it is in its current configuration, water in Barton Springs Pool is no longer drawn down when combined flows are less than 54 cfs (City of Austin, 2013). It is possible that not only Old Mill Spring but also Eliza Spring could cease to flow during an Extreme Drought under current (2014) withdrawals without additional curtailments, even if the gates of Barton Springs Pool were to remain closed. The effect of this circumstance on the Covered Species at Eliza Spring is unknown, but with no-flow conditions at Old Mill Spring, reproduction appears to cease, food becomes scarce, and seasonal high temperature in the surface environment causes mortality from respiratory distress.

Recent statewide initiatives that involve the establishment of a 50-year DFC and the associated amount of MAG have increased the efficacy of the District's permitting program for managing the Aquifer under this HCP. In effect, the District was able to incorporate biological resource conservation into its drought management program and reset the sustainable yield of the Aquifer.

Under these initiatives (House Bill 1763, passed by the 79th Legislature, now reflected in various sections of Chapter 36 of the Texas Water Code), the District worked with the TWDB to use new numerical and probabilistic models and scenarios that estimate long-term consequences for Barton Springs flow under various pumping and climatic scenarios (Hunt et al., 2011). Accordingly, the District has used the results of groundwater modeling and made associated revisions to the District's programs of groundwater management under its continuous incremental/rational planning approach for adaptive management. These activities are described in Section 4.1.2, Historical Perspective of Covered Activities. Adaptive management is described in Section 6.4, District HCP Adaptive Management Process.

At least three groundwater models for the Aquifer (Slade et al., 1985; Scanlon et al., 2001, as modified by Smith and Hunt, 2004; and Hutchison and Hill, 2010) now exist that can help assure better management of the Aquifer and protection of the Covered Species. Each model has specific biases and assumptions and differing means of generating outputs. One may be preferable for average aquifer conditions, and another may be better suited to analyzing conditions comparable to the DOR. No one model is ideal for predicting all present and future aquifer conditions and responses. All three models seem to confirm that, other factors equal, under prolonged severe drought, one unit of pumpage reduces springflow by that same unit. For example, a regulatory program measure that reduces the total pumpage during drought by 0.5 cfs from the amount that would otherwise be allowed would correspondingly result in a springflow at Barton Springs that is higher by roughly the same amount (Hunt et al., 2011).

The newest model, developed by the TWDB in support of the MAG determination (Hutchison and Hill, 2010), takes an approach that is likely to represent actual long-term aquifer performance in a general sense. The new model is more of a predictive tool that captures the range of uncertainty in real-world performance than previous models.

The models of Scanlon et al. (2001) and Smith and Hunt (2004) addressed, by calibration to actual springflow, all known/documented sources of recharge during their calibration periods. However, there is now evidence of two additional sources of recharge to the Barton Springs segment of the Aquifer that none of the models explicitly incorporate, both of which have potential implications for estimating and managing extreme low flow and drought conditions at Barton Springs.

One source is the southern groundwater divide. A recent study has shown surface water from the Blanco River can flow northward into the Barton Springs segment from the San Antonio segment during drought conditions (Smith et al., 2012a). The effectiveness of the divide between the two Edwards Aquifer segments dissipates at low flows, and recharge occurs preferentially to the lower-elevation Barton Springs segment. Although the Blanco River flowed continuously during the DOR, increased pumpage in its watershed now has adversely affected its base flow in the Contributing Zone, and flow might cease during Extreme or Exceptional Droughts. Hunt et al. (2012b) showed base flow in streams and low springflow decreased during the 40 years preceding the study. Part of the cause of the decrease could be climate change, over which the District has no control; but a likely cause is withdrawals in the Contributing Zone, which affect springflow and base flow of creeks. The District also has no control over withdrawals in the Contributing Zone. Another recent study (Land et al., 2011) has shown the potential for some groundwater in the San Antonio segment to bypass San Marcos Springs and flow toward Barton Springs under drought conditions. The induced recharge from this indicated "leaky divide" would tend to flatten the springflow recession curve at Barton Springs (make springflow over time decrease more slowly) during severe droughts, even during exceedingly low groundwater levels in the San Antonio segment. However, the amount of recharge from these sources that would actually occur has not been adequately simulated, and its potential significance to flow at Barton Springs under severe drought conditions has not been quantified.

The second source of recharge tends to contradict the assumption that groundwater availability and springflow will decrease as a result of urbanization and increased impervious cover in the Recharge and Contributing Zones of the Barton Springs watershed. Investigators have determined that there is substantial "indirect recharge," or leakage from utility networks (water mains, wastewater and storm sewers, and on-site sanitation systems), lawn irrigation return flow, and stormwater management infiltration devices constructed in the Barton Springs watershed. These indirect sources of recharge tend to offset the decrease in direct infiltration recharge caused by increased impervious cover (Wiles and Sharp, 2008; Garcia-Fresca and Sharp, 2005; and Sharp and Garcia-Fresca, 2004; Sharp, 2010).

Leakage from pressurized water mains, for example, are known to result in utility-scale, unaccounted-for water losses on the order of 10–30% (Foster et al., 1994). Losses on the order of 12% have been measured in the service area of the COA (Sharp and Garcia-Fresca, 2004). Irrigation return flow, or overwatering of lawns, parks, and other turfs and pervious landscapes, is especially common in summer, when the impacts of drought and low flow on the Barton Springs complex may be severe (Garcia-Fresca and Sharp, 2005). A recent study indicates that total recharge to the Barton Springs segment in a developed watershed is estimated to be nearly double that under its pre-urban conditions (Sharp and Garcia-Fresca, 2004). In addition, although it was estimated that on average only 4% of the total recharge during 1999–2009 was from anthropogenic recharge sources, the monthly percentage from anthropogenic sources could vary greatly, ranging from less than 1% to 59% of total recharge (Passarello, 2011). This indirect recharge source has increased significantly since the DOR calibration period (Smith and Hunt, 2004), when the watersheds were much less developed than now. To date (2014), this additional recharge has not been explicitly included in any of the Barton Springs aquifer availability modeling studies.

The quality of indirect recharge is likely to be poorer than native, meteoric Edwards groundwater. However, there is a considerable amount of dilution and possibly attenuation of pollutant concentrations in such water by the time it reaches the water table (saturated zone of the Aquifer). In fact, the studies noted in the previous paragraph suggest that the present water quality in springflow during low flow may be a result of the combination of native and indirect-recharge water sources.

In summary, some of the principal considerations related to variation in springflow at Barton Springs that are important to the Covered Species are:

- Springflow can be highly variable. Extreme low and extreme high daily mean flows differing by nearly 17-fold have been recorded.
- The lowest measured daily flow during the DOR (1950–56) was approximately 10 cfs. The lowest springflow during other 7-year periods not including the DOR years during the 1913–2013 period of record are considerably higher, typically in the mid-teens.

- There are more than 1,200 operational wells in the Aquifer. The maximum monthly pumpage was13.6 cfs in August 2008, and since then, under more recent regulatory constraints, the monthly pumpage of wells with permits has ranged between 4.3 and 12.2 cfs, averaging 7.5 cfs.

- In recent years, several individual, severe droughts have produced observable adverse impacts on the Covered Species' habitat at all spring outlets, with DO-caused impacts at Old Mill Spring and Eliza Spring. The habitat typically has not had time to recover from those impacts between droughts (City of Austin, 2013).

- Groundwater flow models allow for predictions of future aquifer and springflow conditions. They indicate that pumpage and springflow are related on a 1:1 basis during Extreme and Exceptional Droughts. A recurrence of DOR conditions with current (2014) pumpage would result in springflow considerably lower than the record low of 10 cfs.

- It is not known whether and to what extent newly ascertained sources of additional recharge to the Aquifer affect the quality of the habitat of the Covered Species during Exceptional Drought.

3.2.2.2 Ecological Setting

3.2.2.2.1 Overview of Habitat Characteristics and Supported Populations

The four spring outlets of Barton Springs and their associated subterranean areas form the only known habitats for the Covered Species. These habitats and other supported flora and fauna are described in substantial detail in Appendix C.

The salamander populations at Barton Springs experience relatively stable aquatic environmental conditions in their habitat compared to typical lotic (flowing stream) ecosystems. Changes in environmental parameters[8] are typically gradual and within fairly narrow ranges, with the extremes generally associated with floods and prolonged droughts. These conditions consist of perennially flowing spring water that is usually clear, has a neutral pH (~7) (neither acidic nor basic), and maintains cool annual temperatures of ~21 °C (~70 °F) (Service, 2005). As is typical of large, groundwater-dominated, springflows, Barton Springs flow on the falling limb of the recession curve (period of decreasing flow after an increase in flow associated with a storm) generally shows a narrow temperature range (stenothermal). During wet periods, springflow on the rising limb of the recession curve (period of increasing flow after a storm) may be more affected by the prevailing ambient temperature of local surface runoff that rapidly recharges the Aquifer immediately following storms (Mahler and Bourgeais, 2013). Clean springflow with a relatively constant, cool temperature is essential to maintaining well-oxygenated water necessary for salamander respiration and survival (Service, 2013b; Service, 2005). DO concentrations differ somewhat among the spring outlets (City of Austin, 2013). At the larger outlets of Barton Springs, DO concentrations range between 4 and 7 mg/L, average about 6 mg/L (Service, 2005), and are directly related to springflow. During low flow and associated low DO conditions, the DO concentration of water after it issues from an outlet will tend to increase, other factors equal, especially in spring run environments owing to re-aeration of the water with low DO

[8] A parameter in an environmental context means a characteristic, feature, or measureable factor that can help define a system. For example, "water quality parameter" commonly refers to a water property or chemical constituent.

concentration. However, the reduced DO solubility of higher temperature water during summer months, likely made higher by pool environments, may limit such DO concentration increases seasonally and/or from time to time (City of Austin, 2013; Smith-Salgado, 2011).

The USGS has documented an increasing amount of nutrients and organic matter over time in the recharge streams of the Aquifer, which may have consequent DO demand. But to date (2014) a relationship has not been established between DO concentration in recharge water and reduced DO concentration at the primary outlet within Main Springs during drought flows (Mahler et al., 2011). However, the COA has recently shown a statistically significant overall downward trend in DO concentrations averaged over the range of Barton Springs flow, from all individual outlets, from 5.7 mg/L in 2000 to no more than 4.5 mg/L in 2014 (Porras, 2014). This general trend likely relates to additional pollutant discharges in the recharge water, although some part of that trend may also relate to deeper and more prolonged droughts during 2000–2014. Sustained low DO concentrations occur primarily during periods of moderately low springflow (Herrington and Hiers, 2010; Turner, 2009; Service 2005). A recent USGS study of the water chemistry associated with springflow extremes over the last several drought cycles (Mahler and Bourgeais, 2013) also shows that DO concentrations at the primary outlet of Main Springs during the period of that study decreased on occasion during the more transient high flows of some storms. The decreases presumably arise from oxygen-demanding materials in the "first flushes" of runoff, and/or also by seasonally warmer temperatures of recharging surface water. Other outlets may reasonably be inferred to experience similar effects in the future, if not now.

Owing to the factors described above, as well as to the natural drought- and withdrawal-induced variations in springflow, habitat conditions likely will support variable numbers of individual salamanders from time to time, even for the same spring outlets and for similar springflows. This is reflected in the variability of the counts of Covered Species made by biologists from the COA. On the basis of observations for each Covered Species at the perennial spring outlets, COA biologists use a mean-plus-one-standard-deviation (SD) metric based on organism abundance density[9] to represent the surface habitat-dwelling population of individual salamanders affected by the City's covered activities—that is, the City's take. But unlike the City's covered activities, the District's Covered Activities potentially affect the entire populations of both Covered Species (not just the population accessible for counting), at least during severe droughts, in both surface and subterranean habitats.

To account for the complex variability in population sizes in estimating take from its Covered Activities, the District HCP stipulates, similarly to the approach used by the COA, that the surface-habitat component of the population for Covered Species is approximated by the observed mean abundance values plus one standard deviation. These statistics are based on the City's extensive salamander censuses, conducted using the same census standards and protocols approximately monthly over an 8-year period ending in 2011 (City of Austin, 2013). The resultant population estimates by spring outlet are shown in Table 3-2. At best, this is an approximation of the surface-habitat population. In particular,

[9] Salamander counts vary between sampling events and with environmental conditions. The mean-plus-one-SD metric represents a consistent way to estimate the actual population that that would be accessible for counting between sampling events. It is based on the average of and variation in sample salamander counts.

Table 3-2: Population statistics of the Covered Species based on census counts.
These estimates are based on counts using a consistent methodology and do not include that percentage of the population that is inaccessible for counting. The population size varies with time but for purposes of calculating take in the City's (Barton Springs Pool) HCP, it is stipulated to be the sum of mean abundance plus one standard deviation. Source: City of Austin (2013).

	Mean Abundance	SD	Observed Population	Range of Counts
Barton Springs salamander:				
Main Springs	74	86	160	5-447
Eliza Spring	349	275	624	3-1234
Old Mill Spring	15	22	37	0-73
Upper Barton Spring	6	12	18	0-100
Total Stipulated Population			**839**	
Austin blind salamander:				
Main Springs	0.4	0.9	2	0-5
Eliza Spring	1.1	2.2	4	0-12
Old Mill Spring	15	22	37	0-73
Upper Barton Spring	0	0	0	0
Total Indicated Population			**43**	

the actual population of the largely subterranean Austin blind salamander is unreliably estimated by this count-based technique. The conclusion is that these are very small populations subject to stressful changes in habitat on a recurring basis, and therefore concern for their continued existence may be well-founded.

It is impossible to accurately determine population size of a subterranean salamander species on the basis of number of individuals counted in surface habitat. So there is little confidence that the population numbers for the Austin blind salamander shown in Table 3-2, which are based only on such observations, are accurate. The small number counts for the Austin blind salamander are almost certainly more a function of its inaccessible subterranean habitat than its actual population size. The counting of the Barton Springs salamander has similar problems associated with accessibility of all individuals for counting, but likely to a much lesser degree. The District stipulates that the population estimate for the Barton Springs salamander in Table 3-2 accounts for such inaccessibility for this Covered Species.

But such a stipulation is considered by the District to be inappropriate for the Austin blind salamander. The District estimates that a more realistic population than that indicated in Table 3-2 for the Austin blind salamander (43) in its entire Service-designated 120 acres of Critical Habitat (Section 5.1.2.2, Austin Blind Salamander) is 1,000 individuals. The District made this estimate by using inference based on density calculated on the basis of observation at Barton Springs and on similar density calculations for the comparable (in function, form, and structure) Texas blind salamander at San Marcos Springs in the San Antonio segment of the Aquifer (EARIP, 2012); and applying a set of rational assumptions with respect to the hydrogeologic setting in the vicinity of the spring outlets[10]. (The District estimate does not take into account the fact that the Critical Habitat designated for the Texas blind salamander is more than two orders of magnitude larger than that designated for the similarly subterranean Austin blind salamander.)

Further, the observation statistics for the Austin blind salamander are not considered indicative of the spatial distribution of their population within their subterranean Critical Habitat. It is possible that such distribution is not well related to springflow conditions at the various outlets. But for purposes of the take assessment for this HCP, the population distribution indexed to Critical-Stage III drought flows at the individual outlets, using COA measurements and analyses (City of Austin, unpublished data, 2014), is stipulated by the District, yielding the following outlet-specific populations for the Austin blind salamander (Table 3-3).

Table 3-3: Estimated population distribution of Austin blind salamander at each outlet.

Spring Outlet	Estimated Population
Main Springs	877
Eliza Spring	111
Old Mill Spring	12
Upper Barton Spring	0
Total	**1000**

These initial outlet populations would be exposed to DO concentrations associated with that particular outlet, although such exposure would be largely in the subsurface and is likely to be an ever-changing mix with time.

For either species, the information available does not afford an unequivocal estimate of the sizes or spatial distribution at a given time of these populations, especially the Austin blind salamander. Further, the number of individuals in these generally small populations likely varies considerably with environmental conditions, presumptively indicating their sensitivity to habitat conditions.

The differences in the counts of observed individuals among the surveys reflect not only the variability in the population size but also the opportunistic life strategies of these species. The observed number of individuals of both Covered Species is relatively small. The differences in the observed numbers of the two species is consistent with the Austin blind salamander being more adapted as a subterranean species and spending most of its life underground (Hillis et al, 2001). Only occasionally does it move onto the epigean (surface or near-surface) environment where it is observable for counting. Conversely, Barton Springs salamander is more adapted to be a surface species, and the individuals observed in censuses are more likely to be closer to the total population.

The population estimates are given here by spring outlet because the distribution of the Covered Species and the DO concentrations differ among the spring outlets. However, unlike the COA

[10] Basis for this calculated approximation: Austin blind salamander surface density of 0.005 individuals per square foot (City of Austin, 2013, Table 11); subterranean density presumed to be one-half surface density; active subterranean habitat at any one time presumed to be one-half the 120 acres of Critical Habitat designated by the Service (2012); percentage of active habitat range that composes inhabitable voids at the prevailing Aquifer water level presumed to be 15% of the active habitat area, with balance either solid rock or smaller, uninhabitable voids.

ITP, in which its covered activities differ among the spring outlets and even within various parts of the outlet habitats, the District's management of groundwater withdrawals cannot be parsed among the spring outlets. Nevertheless, the amount of take that results from the District's Covered Activities is partitioned among the individual spring outlets on the basis of their specific DO-concentration relationship with combined springflow. But simply put, the District's Covered Activities cannot "target" where take occurs and doesn't occur among the outlets, although it is readily apparent that the effects will be disproportionate among the outlets, and take estimates and impact assessment should account for those differences.

3.2.2.2.2 Water Chemistry and Springflow Relationships

Water quantity, water chemistry, and water quality of springflows are interrelated. High flow, especially stormwater runoff, generally is relatively poor quality with respect to many water quality parameters, including suspended solids, nutrients, bacterial loadings, and oxygen-demanding material. But runoff events also are transient. Such transient stormwater has low (below water quality standards for surface water) DO concentrations (Mahler and Bourgeais, 2013) and relatively small TDS concentrations (salinity). Low DO concentration is likely caused by relatively high oxygen demand and/or induced release of water from aquifer storage that is depleted in oxygen, as well as variable, seasonal water temperature that affects DO solubility. Although average flow and especially typical drought flow tends to be generally higher in quality (that is, has smaller pollutant loads than those in stormflow, as drought is prolonged and springflow decreases over an extended period), DO concentration tends to decrease and salinity tends to increase over a somewhat restricted observed range (Herrington and Hiers, 2010). These phenomena during severe drought, when much less or no oxygenated surface recharge to the Aquifer is occurring, appear to be related to the amount of older, more saline water from confined parts of the Aquifer, including possibly the hydrologically connected Saline Zone or underlying Trinity Aquifer, which have much lower DO concentration (Mahler and Bourgeais, 2013; Lazo-Herencia et al., 2011; Johns, 2006). In addition, these studies suggest that the relative contributions to flow at the individual spring outlets, from various flow routes with different DO concentrations and possibly different salinities, could vary with total springflow (Hauwert, 2004) and also affect the relationships observed. The natural introduction of water with relatively low DO concentration and relatively high salinity, regardless of other factors that might be reflected in the water chemistry and quality, is caused in part by the Covered Activities. DO and salinity are the two springflow-related water chemistry parameters that are believed to be of primary potential importance in determining the amount of take of the Covered Species in the spring habitats by the District's Covered Activities.

Dissolved Oxygen and Springflow

The concentration of DO has been known for some time to correlate directly with springflow at Barton Springs (City of Austin, 2013; Herrington and Hiers, 2010; City of Austin, 1998). DO tends to be at relatively high concentrations during periods of high recharge when a large volume of well-oxygenated surface water that is not stormwater enters the aquifer. DO levels are at their lowest when recharge is minimal or nonexistent and springflow is low (Herrington and Hiers, 2010; City of Austin, 1997). Extended or frequent periods of low flow, therefore, can be detrimental to the development, reproduction, and even survival of the Barton Springs salamander. However Norris et al. (1963), while confirming the adverse effects of low DO concentration, also notes that some salamander species physiologically accommodate low DO concentration. Although the Barton Springs salamander persisted through the drought of the 1950s and likely earlier, even more severe and prolonged droughts (Cleaveland, 2006; Cleaveland et al., 2011), its population may have been larger earlier in its history, perhaps even not unique to Barton Springs. But its population size may have been adversely, possibly permanently affected, by prolonged low flows at Barton Springs, particularly if DO concentrations were proportionally low. Depressed DO concentrations also may compound the effects of other stresses on salamander survival, such as increased pollutant loading during drought and low-flow conditions. A key adaptive objective of this HCP is to increase the understanding of the relationships between springflow and DO concentration in the Barton Springs complex and further afield in the Aquifer, and to develop over time an enhanced capability to minimize or avoid anthropogenic lowering of DO concentration through groundwater management during low-flow conditions.

Science staffs at the COA, TWDB, USGS, and BSEACD have collaborated for several years to collect, compile, and analyze water quantity and quality data from the Barton Springs complex. These collaborations have included studying the correlation of springflow, DO concentration, and other relationships. There is considerable agreement that strong correlations exist between springflow and DO concentration, within the ranges of springflow for which data have been collected. There is some variability in the data-collection instrumentation, methods of collection and analysis, and frequency and areal extent of data collected by the different entities, all of which affects accuracy, precision, and/or usefulness of the data. Such limitations in making inferences in this HCP are noted in appropriate places. Further, the relationships differ among the individual spring outlets. Appendix D summarizes the outcomes of several representative investigations of these relationships conducted by the COA Watershed Protection Department, describing the results of these studies in detail and also presenting summary statistical analyses of the data.

Reliably measuring in-situ DO concentration of groundwater is a well-known challenge. In one such recent study of the Aquifer (Lazo-Herencia et al., 2011), median DO concentration of native groundwater in the Recharge Zone was 6.4 mg/L, and median DO concentration in the Confined Zone was substantially lower, 2.0 mg/L. These results support the notion that more water from the Confined Zone adjacent (both laterally and vertically) to the spring outlets discharges from the outlets at low water levels, resulting in a decrease in DO concentration with decreasing springflow. A more recent USGS study (Mahler and Bourgeais, 2013) of the Aquifer and flow at the primary outlet of Main Springs over a 6-year period with high and low groundwater levels and springflow found DO concentrations fluctuating by a factor of two. In addition, the study data show DO concentration generally related inversely to springflow temperature and directly to springflow; and Mahler and Bourgeais (2013) note that both relationships are likely to be strengthened by climate change. The lowest DO concentration observed by those investigators was 4.0 mg/L, consistent with a water-source model of mixed water types in approximately equal proportions. Main Springs consistently has higher DO concentrations than the other outlets and considerably lower DO concentrations have been measured at the other outlets than at Main Springs.

A salient aspect of the data and analyses in Appendix D is that relatively few paired, combined springflow and DO data exist in the springflow domain below 20 cfs, which is the more critical region for assessing significant take. Figure 3-7 shows the range in predictions of DO concentration for the aggregated sub-outlets at Main Springs that can be expected from various regression models[11], which were developed by COA staff under various boundary conditions in the zone of flow less than 20 cfs.

Regression models for individual spring outlets, such as those shown in the figures in Appendix D, do not have well-established, reliable predictors of DO concentration with combined springflow in the zone of flow less than 20 cfs, owing to sparse or non-existent data. For example, from 1978 to the present time, the minimum DO concentration *observed* by the USGS at the primary outlet of Main Springs is approximately 4 mg/L, when the combined springflow was reported to be 13 cfs in August 2009 (the previously noted measurement difficulties notwithstanding). The COA regression model (Saturation Growth, Figure 3-7) for Main Springs indicates that the *predicted* DO concentration would be 3.4 mg/L at a discharge of 13 cfs, which is lower than the actual observed value at that discharge (The USGS collected its data at just one outlet, the primary outlet of Main Springs, but the regression relationships were developed by the COA for the aggregated sub-outlets of Main Springs). The logarithmic function used in this and some of the other models predicts that DO concentration would decrease to 0 mg/L at or above a discharge of 0 cfs. Although this outcome is conceivable, the prediction is a product of the mathematics, not DO and springflow data at very low values, which are unavailable. Other models predict different but also conceivable outcomes, with DO concentration decreasing only to about 4 mg/L. Those outcomes appear to be more in keeping with results established at high flows where there are data to support the mathematical relationships. USGS staff, using a multivariate model, calculated that the DO concentration at the primary outlet of Main Springs would be 3.99 mg/L under no-flow conditions (Mahler and Bourgeais, 2013). The same caveats regarding lack of actual DO-concentration data at such low flows apply to these results as well.

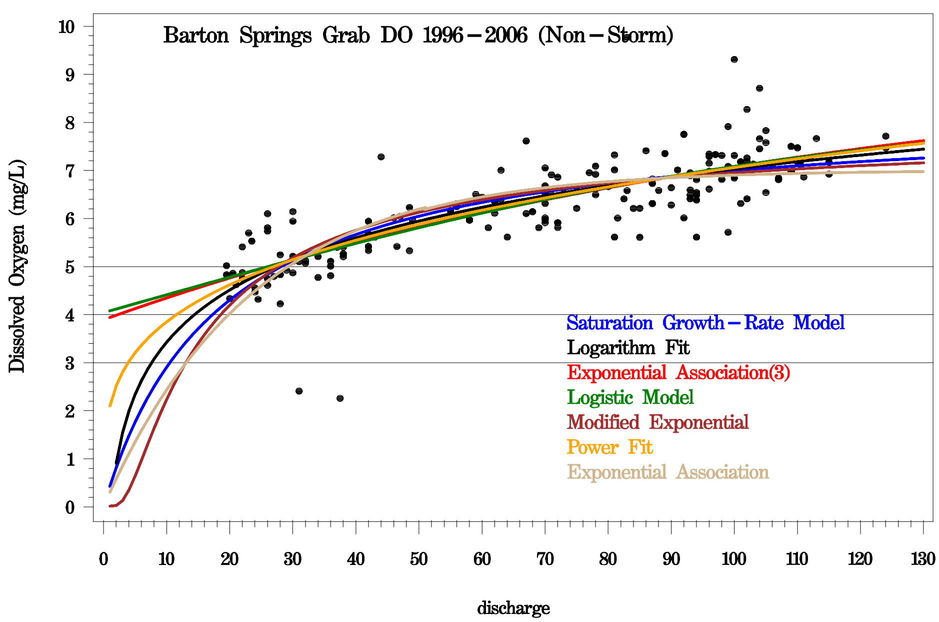


Figure 3-7: Various regression models representing relationships between springflow of the aggregated sub-outlets of Main Springs and dissolved oxygen concentration.
These regression models are based on flow data that do not extend into flows less than about 20 cfs. Source: Turner (2007).

[11] A regression model in this context is an equation that relates DO concentration (dependent variable) to springflow (independent variable). Several different techniques are available to develop regression models.

In assessing the usefulness of the existing data and analyses for evaluating adverse effects and impacts of take on the Covered Species, their limitations and uncertainties should be considered. Some of the more important of these limitations follow.

In the laboratory study of salamander response to the stressor depressed DO concentration (Poteet and Woods, 2007), which is presented in Section 5.2.1, Experimental Assessment of Salamander Responses to Changes in Water Chemistry Related to Springflow, there were only 35 DO concentration observations less than 4.5 mg/L for Main Springs in the available USGS dataset that was used to assess the usefulness of the laboratory results. Woods et al. (2010) extended that assessment with an ecological hazard assessment and found no statistically significant relationship between low flow and associated DO concentration for this limited USGS data set. Even less information for Eliza Spring and Old Mill precluded similar evaluations for those sites. The relationship between springflow and DO concentration for flows less than 20 cfs is important to a quantitative assessment of take, but that relationship is not known with certainty.

Nevertheless, there is clear evidence of depressed DO concentration with smaller springflows observed in the *overall* datasets at specific spring outlets. In particular, DO concentration at Old Mill Spring is known to plunge when the combined Barton Springs flow declines toward 20 cfs. Sustainable yield simulations done by the District in 2004 indicate that under 1950s DOR conditions and large withdrawals, water from the Saline Zone has a greater potential to move into the freshwater part of the Aquifer (Smith and Hunt, 2004). Water in the Saline Zone tends to be more depleted in DO than water in the unconfined and freshwater parts of the Aquifer.

Not all of the data available for the Barton Springs complex have been collected with the same instrumentation, over the same time period and frequency, or compiled and analyzed using the same protocols. Most of the DO data shown in Figure 3-7 were collected by the COA, using grab-sample data in the various spring orifices, some stationary and some mobile. If different data sources were to be used and compared to the results described, the outcomes in the zone of extreme low flow may appear significantly different. In particular, the datasondes yield lots of data related to all flow conditions. Although useful for some purposes, data from high (including storm) flows, which can have low DO (Mahler and Bourgeais, 2013), confounds the analysis and prediction of DO concentration during extremely low base flow. And extremely low flow is the most import to the Covered Species in assessing take.

Further, at very low flows, the reliability of individual springflow measurements is impaired because of magnified effects of factors not related to springflow—factors such as differences among measurement personnel, altered or unstable cross-sections, and changes in backwater effects from slight rises and falls in Lady Bird Lake elevation during discharge measurements. Hunt et al. (2012a) showed that flow measurements can vary by as much as 30% during low flow. So there is a corresponding uncertainty in the correlation among flows at different times and in the correlation of flow to DO concentration.

There is also uncertainty, if the DOR were to recur, as to how low and by which influences the combined springflow at the Barton Springs complex might decline. The current (2014) drought management program of the District and this HCP is designed to provide a base springflow during a DOR recurrence (refer to Section 6.2.1.8, Addressing Quantitatively the Established Desired Future Conditions, for the desired outcome of proposed HCP measures). This regulatory program is indexed to authorized groundwater use, but actual groundwater use in aggregate historically has tended to be less than the prevailing curtailed authorized use (reflected in Figure 3-9), allowing for higher-than-predicted springflow. Further, the regression models described in this section are limited by the lack of data under extreme low-flow conditions as well as variations in source data and other factors noted. No known scientific studies integrate other independent but related factors into predictions of DO concentration under extreme low-flow conditions. Nevertheless, given the considerable uncertainty that must be addressed in such situations, the regression models provide understanding and help frame and prioritize management alternatives on the basis of the possible consequences of various actions (or no action).

An analysis was done of DO concentration and several other water quality parameters at Barton Springs over a 25-year period, adjusting for variations in springflow (Turner, 2000). The analysis of water quality records, collected by the COA from 1975 to 1999, indicated statistically significant changes in DO concentration over the 25-year period, possibly related to watershed urbanization. DO concentration in both high and low springflows decreased over time. The median DO concentration decreased by about 1 mg/L over the 25 years 1975–99, from 6.4–6.8 mg/L in 1975 to 5.45–5.7 mg/L in 1999, a decrease of about 15%. Sampling has been more frequent recently, leading to a higher probability of observing extreme events. Therefore it is possible that the observed change is a sampling artifact (Turner, 2000). Enhanced nonpoint-source pollution controls in the Barton Springs watershed have been initiated by the COA, Travis County, and several municipalities to arrest or slow this decline, but recent statistical analyses by the COA suggest that the temporal trend in decreasing overall DO concentration is continuing, and the median is now less than 4.5 mg/L (Porras, 2014). A long-term change in DO concentration of greater than 1.0 mg/L is likely meaningful in any isolated aquatic habitat. Trends in other water quality parameters such as nutrients and total suspended solids in springflow were not as clear or notable (Turner, 2000). A more recent USGS report on water quality trends in the Barton Springs recharge streams and at Barton Springs (Mahler et al., 2011) indicated that low flow during dry periods did not show water quality impacts by suspended solids, nutrients, and bacteria at Barton Springs; but during wet periods and stormflows, those parameters in streams, the Aquifer, streamflow showed significant increases associated with watershed development.

Salinity and Springflow

The specific conductance of springflow, a measure of the concentration of TDS (salinity) in the water issuing from the Aquifer, as well as individual ion concentrations, have been known for some time to increase as springflow decreases (for example, Slade et al., 1986; Senger and Kreitler, 1984). The general relationship is shown in Figure 3-8, depicting paired specific conductance and springflow data collected by the COA over a 7-year period that includes very high and very low springflow (Herrington and Hiers, 2010). Specific conductance varies within a fairly narrow range. The difference in specific conductance of the average flow and specific conductance of the lowest flows in this dataset is about 75 μSiemens/centimeter. This corresponds to a variation in TDS of less than 50 mg/L. That salinity variation between average flow and the lowest flows is not much more than the salinity variation in typical flows of the same magnitude. Even at the lowest flows the highest TDS concentrations of springflows reflected by these data are about 475 mg/L, less than one-half the concentration considered freshwater (less than 1,000 mg/L TDS) and supportive of aquatic life. However, TDS or specific conductance data for extreme low flow, such as would exist during a recurrence of the DOR, are not available, so the actual salinity of such DOR flow is unknown.

Researchers have postulated that the increase in salinity under low-flow conditions is caused by a greater proportion of springflow being contributed by water from the Saline Zone (Slade et al. 1986; Johns 2006). Low water levels in the freshwater zone of the Aquifer associated with low-flow conditions can result in an increase in pressure from the Saline Zone toward the freshwater zone of the Aquifer. Similarly, water from the underlying Trinity Aquifer could possibly migrate upward along faults that relate to the spring outlets, but there is no evidence of such interformational flows elsewhere in the District (Wong et al, 2014; Smith and Hunt., 2011). So the Trinity Aquifer seems a less likely source of brackish/saline water to the outlets. On the basis of hydrochemical data analysis and use of mixing models, Hauwert et al., (2004) suggested that about 3% of the springflow at Old Mill and 0.5% at Eliza and Main Springs might be derived from such sources during low-flow (17cfs) conditions. This is consistent with the observed small but statistically significant differences in salinity among the various spring outlets. Not all spring outlets have such salinity variation, presumably because of differences in water source, contributions from different flow routes, and degrees of mixing (Johns, 2006). Old Mill Spring tends to have the highest specific conductance of the four spring outlets. The relatively high specific conductance is most likely attributable to the proximity of Old Mill Spring to the Saline Zone and influence of the Saline Zone on flow routes that provide a substantial percentage of the water to that particular outlet (City of Austin, 1998). The consequences of the relatively small rise in average salinity on the Covered Species are not known.

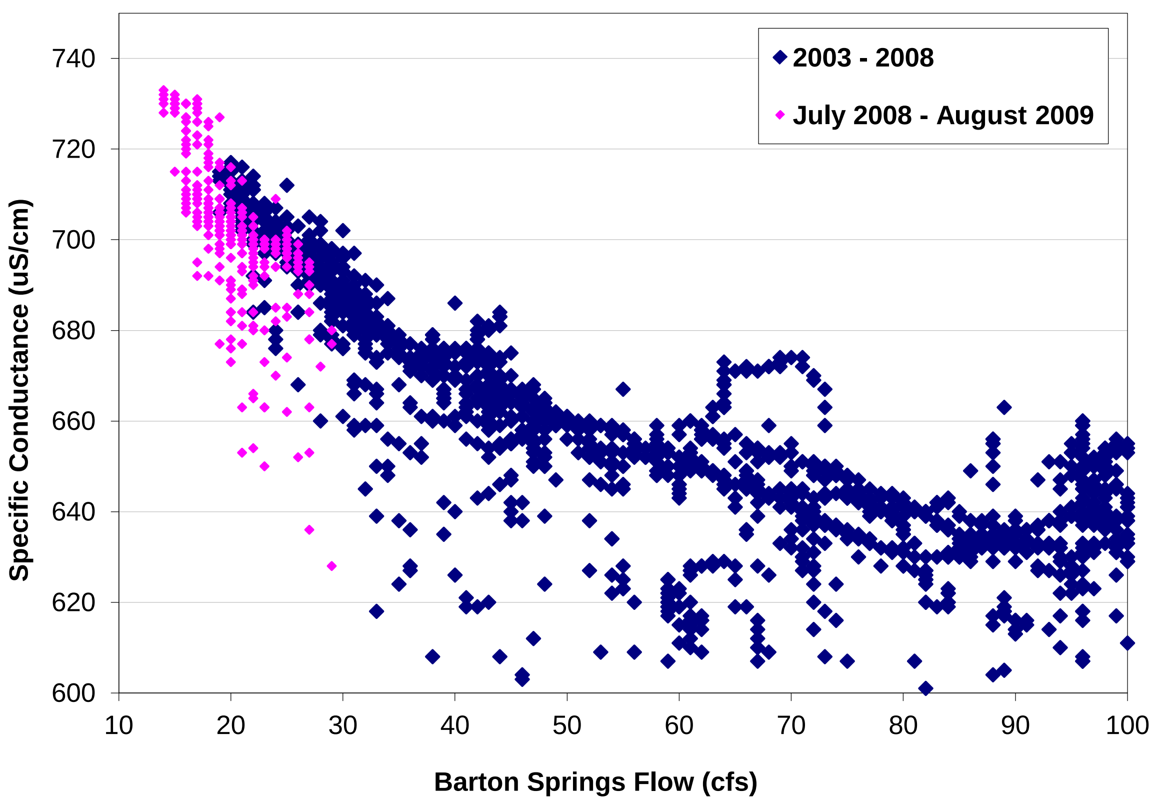


Figure 3-8: Inverse relationship between springflow and water salinity, expressed as specific conductance.

The relatively small range of variation in specific conductance corresponds to a range in TDS of about 70 mg/L. Source: Herrington and Hiers (2010).

3.2.3 Antecedent Conditions in ITP Area

There are pre-existing conditions in the ITP Area, originating prior to the initiation of the HCP and continuing to the present day, that have significant bearing on the affected environment of the Covered Species and on the ability of the District to manage the Aquifer. Accordingly, consideration of the protective enhancements and conservation measures taken under this HCP must be framed within the context and realities of these pre-existing conditions.

Many of these conditions stem from historical patterns of development and associated water and land use, all of which have various legal protections under other law but nevertheless influence the quality and quantity of water discharging from Barton Springs.
These historical land use and development trends in the ITP Area have contributed to a gradual but progressive degradation of surface recharge quality (Mahler et al., 2013) and consequently in the water quality of springflow discharging at Barton Springs (City of Austin, 2013); but so far such springflow degradation has been small. The District does not have authority to manage or control land use or the quality of Barton Springs discharges that arise from the impact of development on surface water that recharges the Aquifer.

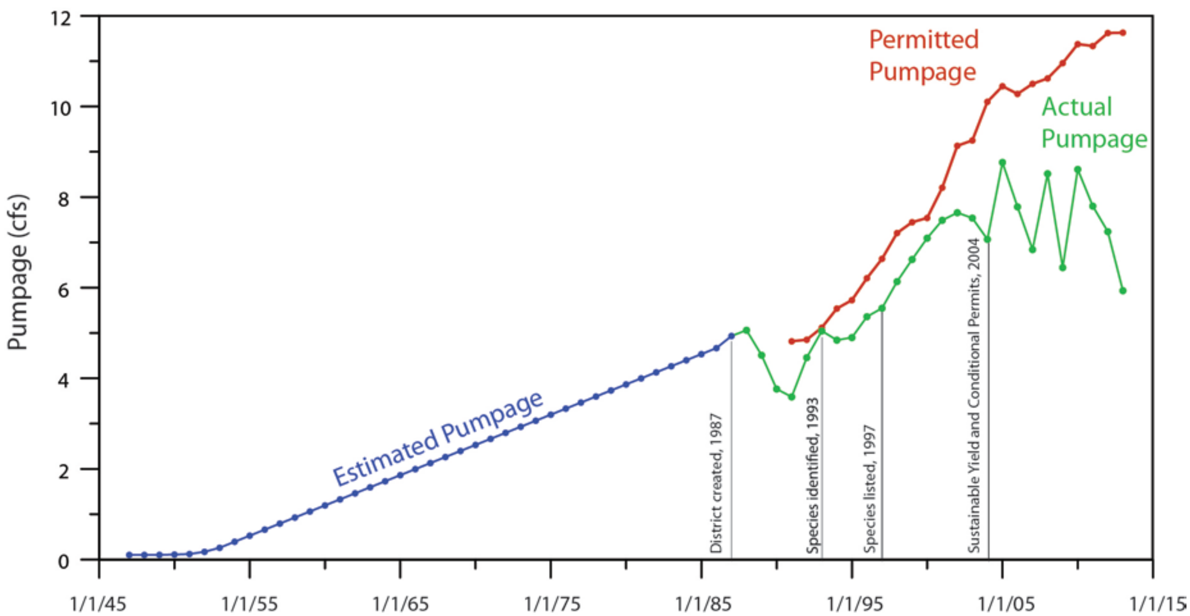


Figure 3-9: Pumpage history showing District milestones.
Actual Pumpage rates are annual averages, in cfs, for nonexempt wells in the District. Data before 1988, when wells first began to be metered, are estimated; after 1988 data are self-reported meter readings. Source: Data through 2006 are from: Hunt et al., 2006. Data after 2006 are unpublished BSEACD data.

Figure 3-9 illustrates the history of withdrawals from all permitted wells in the Aquifer, in association with several District milestones. Before the establishment of the District in 1987, there was no legal authority or ability to regulate groundwater withdrawals from the Aquifer. The Aquifer then was a readily available, sole source of high-quality water that served a growing suburban and exurban population. Not until 1989, when the first groundwater management plan and rules were adopted by the District and meters began to be set on permitted wells, was there any operational permit program to manage groundwater withdrawals in this rapidly developing area. By 1989, the estimated average pumpage in the District was about 5 cfs.

Before federal listing of the Barton Springs salamander as endangered in 1997, there was no basis of reference to measure how much groundwater withdrawals or what limitation on withdrawals would be needed for protection of the salamander population at Barton Springs. In the mid-1990s, when the Barton Springs salamander was first described as a newly identified species and subsequently listed as endangered, *actual* pumpage under approved permits or exemptions to permits was already in the range of 5 to 6 cfs, contributing then to diminution of and natural variation in springflow during droughts.

From an historical perspective, the District's intent and actions in developing this HCP are a continuation of those the District has voluntarily and proactively followed, inasmuch as the District's mission was consistent with the Act's purpose; that is, reducing water demand and/or increasing supply that results in source-substitution during drought to preserve Aquifer water levels and springflows, and thereby generally reduce adverse impact to the habitats of the Covered Species. In 2004, when the District initiated the habitat conservation planning process, the *actual* total pumpage from the Aquifer, under approved permits and exemptions to permits, was about 7 to 8 cfs, even though authorized pumpage under permit was just over 10 cfs. This HCP, which is the result of a long-term planning process, now establishes the District's commitment to implement actions that avoid additional adverse impacts to the Covered Species and to minimize and mitigate those impacts of District activities that cannot be avoided.

Drought is another, different type of pre-existing condition that is also germane to this HCP. The ITP Area is prone to severe drought cycles, and the Covered Species are stressed "naturally" on a variable, generally cyclic basis by drought in exactly the same way the regulated withdrawal of groundwater by wells as a Covered Activity stress the species. (Figure 3-6, a hydrograph of springflow, illustrates the cyclic nature of drought in the Area.) So the effects of the Covered Activities, which represent a specific level of take that is analyzed in Section 5.2, are superimposed on similar but more variable effects from a natural drought cycle that exists regardless of whether and how much groundwater is withdrawn by wells in the Aquifer in the ITP Area.

3.2.4 Protected Species in ITP Area

Table 3-4 lists species that are federally protected in the three counties in which the ITP Area is located (Service database, http://www.fws.gov/southwest/es/ES_Lists_Main.cfm, accessed December 30, 2013). Most of these species are either only found in areas of these counties that are well outside the ITP Area or otherwise are not known to exist in the ITP Area. Only the first two species listed are known to exist in the ITP Area and may reasonably be expected to have habitat affected by the proposed Covered Activities; and those two species are the proposed Covered Species for this HCP.

Table 3-4: Federally protected species in Travis, Hays, and Caldwell Counties, Texas. Status is denoted as endangered (E), threatened (T), candidate (C), and of concern (D) (Service, 2014).

Group	Species	Common Name	Status
Amphibians	*Eurycea sosorum*	Barton Springs Salamander	E
	Eurycea waterlooensis	Austin Blind Salamander	E
	Eurycea tonkawae *Eurycea nana* *Typhlomolge rathbuni*	Jollyville Plateau Salamander San Marcos Salamander Texas Blind Salamander	C T E
Birds	*Dendroica chrysoparia*	Golden-Cheeked Warbler	E
	Vireo atricapilla	Black-Capped Vireo	E
	Grus americana	Whooping Crane	E
Insects	*Texamaurops reddelli*	Kretschmar Cave Mold Beetle	E
	Rhadine Persephone *Heterelmis comalensis* *Stygoparnus comalensis*	Tooth Cave Ground Beetle Comal Springs Riffle Beetle Comal Springs Dryopid Beetle	E E E
Arachnids	*Texella reddelli*	Bee Creek Cave Harvestman	E
	Texella reyesi	Bone Cave Harvestman	E
	Tartarocreagris texana	Tooth Cave Pseudoscorpion	E
	Leptoneta myopica	Tooth Cave Spider	E
	Circurina wartoni	Warton's Cave Meshweaver	C
Plants	*Zizania texana*	Texas Wild Rice	E
Fishes	*Gambusia georgei* *Etheostoma fonticola*	San Marcos Gambusia Fountain Darter	E E

4.0 Proposed Actions

4.1 Proposed Covered Activities

The District seeks coverage under the prospective Incidental Take Permit (ITP) for withdrawal of groundwater from the Aquifer by well owners/operators holding a valid permit from the District for their groundwater supply that is managed by the District. These activities result from time to time in incidental take of the Covered Species by adversely affecting the quantity and associated chemistry of water that is naturally discharged from the Aquifer at Barton Springs. The activities for which the District seeks coverage arise from groundwater withdrawals from nonexempt registered wells that are authorized and regulated under the District's permitting program. Limits on groundwater withdrawals apply only to District-permitted wells. The withdrawals are considered a Covered Activity only if the well and the permittee are in compliance with the District's rules, including permit conditions, prevention of waste, and water conservation plan and drought contingency commitments. These are lawful activities with a publicly beneficial purpose, and any associated take, as defined by the Endangered Species Act (Act), is incidental.

The Covered Activities directly relate to and affect primarily the groundwater resources and the groundwater-user community in the District. The withdrawal of groundwater from the Aquifer by this regulated community using wells registered and permitted by the District is a principal activity for which the ITP is sought. It is also important to the understanding of the HCP that the District's regulatory program is the primary vehicle for the proposed conservation measures for the Covered Species.

The regulation of the groundwater-user community, which is accordingly also the focus of the HCP avoidance, minimization, and mitigation measures, is described in Section 4.1.1, Regulated Groundwater Community. The evolution and status of this regulatory program, its statutory and regulatory authorities, and the public participation in its development are then characterized in following subsections to provide a historical context and the current status of this vehicle under which compliance with the ITP provisions will be assured.

4.1.1 Regulated Groundwater Community

The District is requesting coverage under the ITP for water withdrawals managed under its regulatory program, which controls the conditions under which groundwater is used in the District and especially the amount of groundwater withdrawn by permitted well owners. The large majority of permitted withdrawals are dedicated to providing for public water supply though water utilities. However, the end-user customers of these utilities are not directly regulated by the District so they are not included in this community (Table 4-1). Their individual use of Aquifer water is not considered part of the Covered Activities. Components of the District regulatory program consist of permitting, compliance monitoring, enforcement, assessment and administration of various District fees, user conservation planning, and user drought contingency planning and response. The purpose of the program is to reduce withdrawals of groundwater from the Aquifer to those minimum volumes reasonably needed by well owners and permittees during drought and non-drought periods to conserve the water supply for as long as possible and to maintain sufficient flows at Barton Springs to support the Covered Species. However, the maximum reductions in water withdrawals prescribed under this program are unable to completely avoid adverse effects on the Covered Species during severe drought.

Table 4-1: District public water system permittees.
Only District permitted volumes and wells reported in table. Water utilities may have additional alternate supplies or wells permitted through other GCDs.

	Permitted Volume				
Water Utility	**Gal/Yr**	**CFS**	**# of Wells**	**End-users (1)**	**#. of Connections (1)**
Aqua Texas (Bear Creek)	12,098,000	0.051	2	276	92
Aqua Texas (Bliss Spillar)	51,500,000	0.218	21	2211	295
Aqua Texas (Leisurewoods)	88,764,000	0.376	6	1338	446
Aqua Texas (Mooreland)	6,000,000	0.025	2	156	52
Aqua Texas (Onion Creek)	36,300,000	0.154	3	696	232
Aqua Texas (Shady Hollow)	80,000,000	0.339	2	699	233
Arroyo Doble Water System	52,800,000	0.224	2	912	304
Cimarron Park Water Company	118,000,000	0.500	2	2058	686
City of Buda	275,000,000	1.166	4	9882	3,294
City of Hays Water Department	15,400,000	0.065	2	233	89
City of Hays Elliot Ranch	54,450,000	0.231	2	618	206
City of Kyle	330,000,000	1.399	1	24,261	8,087
City of Sunset Valley	18,590,000	0.079	1	1326	442
Creedmoor-Maha WSC	235,065,600	0.997	6	6819	2,273
Goforth Special Utility District	350,900,000	1.488	5	15,612	5,204
Huntington Utility LLC (SWWC)	18,000,000	0.076	1	378	126
Monarch Utility	324,400,000	1.375	4	6396	2,132
Mountain City Oaks Water System	43,164,000	0.183	1	696	232
Mystic Oak Water Co-op	7,700,000	0.033	2	132	44
Oak Forest Water Supply Company	25,500,000	0.108	2	321	107
Ruby Ranch Water Supply Company	52,300,000	0.222	5	699	233
Slaughter Creek Acres Water Company	14,000,000	0.059	2	273	91
Twin Creek Park	12,000,000	0.051	1	285	95
Village of San Leanna	31,651,200	0.134	3	497	213
Totals	**2,253,582,800**	**9.553**	**82**	**76,774**	**25,208**

(1) Data obtained from TCEQ Public Water System Database.
http://www14.tceq.texas.gov/iwud/index.cfm?fuseaction=showusermenu , accessed August 18, 2014.

More than 1,200 water wells exist in the District's jurisdictional area (Figure 4-1). Nearly all of them are now registered with the District, and nearly all of their withdrawals (almost 97%) currently (2014) are from the Edwards Aquifer. Many more wells are in the HCP Planning Area outside District boundaries, but none of those are in the Aquifer. Most wells in the District draw water only from the Aquifer. Moreover, use of other aquifers in the District currently is very small. Most wells serve small-volume users. They are typically domestic wells for individual households that are exempt from permitting and therefore not regulated or monitored by the District as to the amount of water withdrawn. Water withdrawals from these wells are not Covered Activities.

The District classifies its registered wells into four major categories, which determine whether and specify how the District regulates its groundwater use (BSEACD, 2012). These are summarized in Table 4-2 and characterized below.

Table 4-2: Estimated/authorized groundwater withdrawal by withdrawal type.
Exempt use is estimated from geospatial analysis (Banda et al., 2010); nonexempt uses are 2013 use by the type of permit that authorizes withdrawal. The Nonexempt Historical withdrawal includes 91,525 thousand gallons per year from Trinity Aquifer permits; the remainder is from Edwards Aquifer permits.

Withdrawal Type	Number of Wells	Regulated by District	Estimated/Authorized Withdrawal	
			1,000 gal./Year	CFS
Exempt Use	997	No	105,000	0.4
Nonexempt Domestic Use	77	Yes	21,020	0.1
Nonexempt Historical	110*	Yes	2,462,513	10.4
Nonexempt Conditional	30*	Yes	348,700	1.5

*Some wells may have authorized withdrawal under both historical and conditional production permits. Numbers shown are for the dominant type of authorized withdrawal.

4.1.1.1 Exempt Wells and Users

An exempt well by State law is not subject to the District's permitting program and therefore has no authorized withdrawal limit set by the District. However, they are registered by the District and are subject to District Rules related to well-construction standards and avoidance of "waste" as defined by statute.

Individual exempt wells generally withdraw only small volumes of groundwater. An exempt well is generally defined by statute as a well that is used solely to supply domestic use or to provide water for livestock or poultry if the well is: (1) incapable of producing more than 10,000 gallons of groundwater a day, *and* (2) located or to be located on a tract of land larger than 10 acres. Exempt wells include by definition several other use types: closed-loop injection wells, dewatering wells, oil and gas wells, and monitor wells. There are no oil-and-gas supply wells or dewatering wells registered in the District and, because injection and monitor wells are not designed for the purpose of groundwater withdrawal, aggregate withdrawals from these use types are negligible.

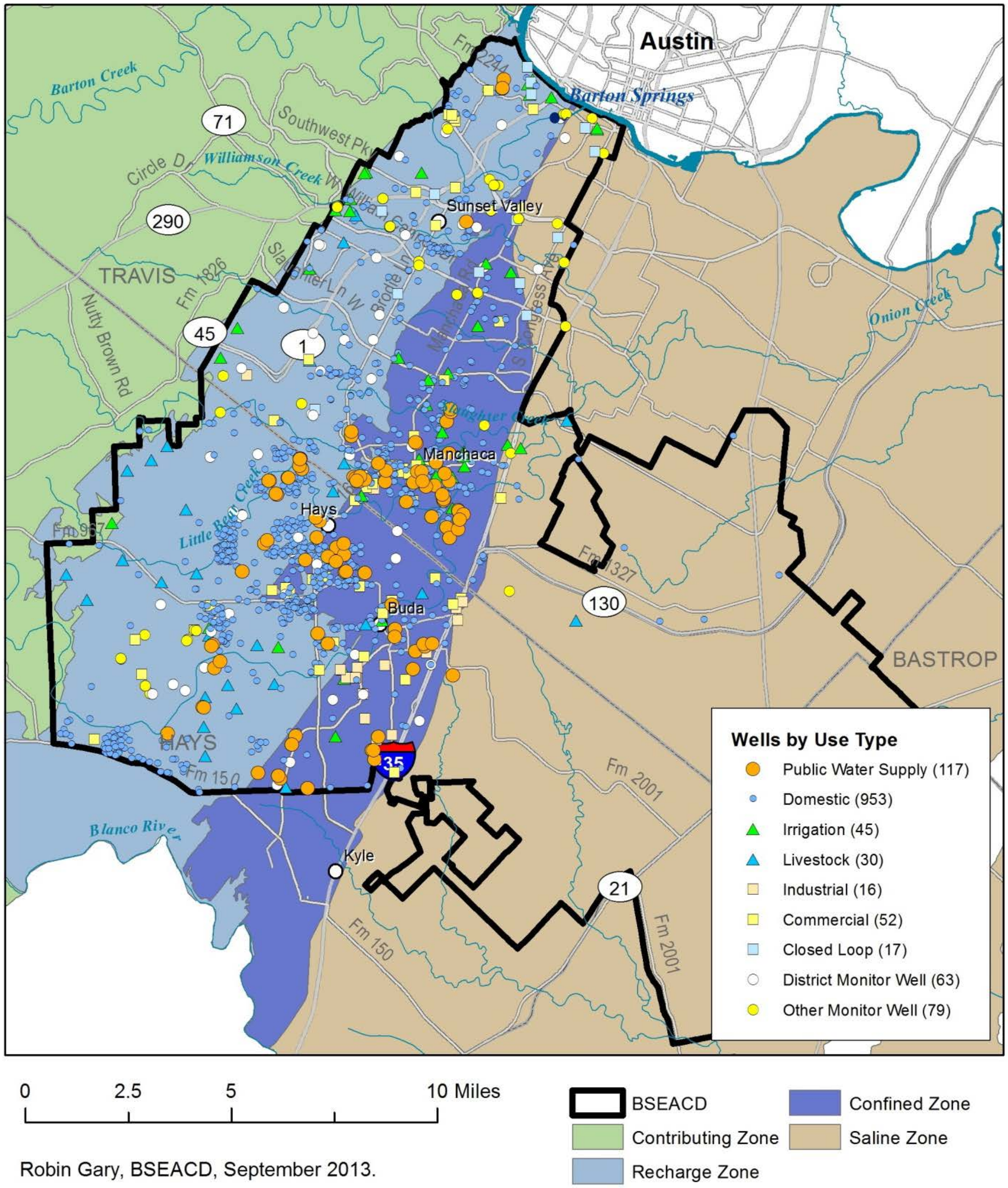


Figure 4-1: Location of wells in District jurisdictional area and use type.
Except for groundwater withdrawals from wells authorized for nonexempt domestic use (Table 4-2), withdrawals from domestic, livestock, monitor, and closed-loop wells are exempt from permitting. The other use types are nonexempt and require a District permit to authorize withdrawals. Source: BSEACD wells database, 2013.

Exempt wells are generally used as water supplies for livestock (including windmill-powered wells) and/or for residences on large-tract household, ranch, or farm lands. The District recently estimated on the basis of GIS analysis that there were about 1,000 exempt wells in the District, but they produced only about 4% of the total volume of groundwater withdrawn by all wells in the District (Table 4-2). Further, the number of wells in service and amount of exempt withdrawals are likely decreasing as these wells age, deteriorate, and are abandoned, and as the ITP Area becomes more developed with centralized water systems (Banda et al., 2010). The specific number of the wells being abandoned typically goes unreported and therefore is difficult to estimate. Most existing exempt wells were in place at the time the District was formed in 1987. Very few new wells in the District meet all the criteria to be exempt.

Exempt wells are capable of only limited withdrawals because they are generally equipped to produce no more than 10,000 gallons per day or the equivalent pumping rate of about 7 gallons per minute. Withdrawals are limited by well size and equipment rather than by regulation. Actual withdrawals are estimated to be more typical of regional domestic-use withdrawals and are substantially less than the 10,000-gallon-per-day withdrawal-capacity limitation (Table 4-2). Actual withdrawals are not known because exempt wells are not usually metered, and owners/operators are not required to report water use or charged for water use at any time. Exempt wells do not have the permits that are used by the District as the vehicle to specify User Conservation Plan (UCP) and User Drought Contingency Plan (UDCP) requirements, so mandatory, enforceable drought-period curtailments are not applicable to them. Therefore, under Service regulations, exempt wells cannot be a Covered Activity for the HCP.

Even though withdrawals from exempt wells by State law are not subject to limitation by the District, the total groundwater withdrawal by exempt wells does affect the allowable amount of water to be withdrawn by other wells during Extreme Drought conditions.

4.1.1.2 Nonexempt Wells and Users

Withdrawal by all nonexempt wells in the Aquifer is regulated through District permits and is a Covered Activity. Permits are the vehicles for implementing the District's drought rules that constitute its Drought Contingency Plan.

All permittees must adopt UCPs and UDCPs, which are integral, mandatory parts of every permit. Templates for UCPs and UDCPs that have been developed by the District and made available to its permittees as guidance are included in Appendix E. UDCPs in particular are central to the District's drought management program. This program involves a declaration by the District Board of the severity of groundwater drought on the basis of actual Aquifer conditions, as defined by the District's Drought Trigger Methodology developed for this HCP. (See Appendix F for details on the drought trigger methodology, and Appendix G for the rule-based definitions of the various groundwater drought stages used by the District for drought management.) Permittees are required to curtail their monthly groundwater use according to the declared drought stage and their approved baseline volume for a given month, as specified in their UDCP. All individual permittees are required to report their actual groundwater use monthly to the District. The District uses these data to assess compliance with monthly UDCP requirements and to initiate pre-enforcement and enforcement actions, if and as warranted, during drought; and to evaluate whether permittees have exceeded their annual authorized withdrawals.

The requirements of UCPs and UDCPs and the penalties for noncompliance are specified by District Rules and the District's Board-approved Enforcement Plan; they are legally enforceable by the District. The District's enforcement scheme includes assessment of daily penalties, up to $10,000 per day, that are indexed to the amount of authorized use, the degree of noncompliance, and drought stage. More information on the District's Enforcement Plan is in Section 6.5.1.4, District Enforcement Program. The District typically achieves immediate compliance for egregious and recurring violations of monthly pumping limits through agreed settlement orders. Such orders apply early resolution incentives through a prescribed reduced percentage of monetary penalties, applicable sanctions, and compliance requirements. But enforcement can also be achieved through litigation in district court, where the full amount of the penalty then becomes a matter before the court. The District has never had to instigate this latter step to achieve satisfactory compliance by permittees.

The relationship between production permit type and degree of curtailment under specified drought conditions is summarized in Table 4-3. The various regulatory drought stages and related curtailment provisions of the District's drought management program are explained in greater detail in Appendices F and G.

4.1.1.2.1 Nonexempt Domestic-Use Wells and Users

A nonexempt domestic-use (NDU) well is a well used by, and connected to, a household for personal needs or for household purposes such as drinking, bathing, heating, cooking, sanitation or cleaning, and landscape irrigation but that does not meet the criteria for exemption from permitting. These wells must be on a single-ownership plot smaller than 10 acres that contains a household. (If on a tract larger than 10 acres, these wells typically would be exempt.) NDUs typically operate under a "general permit by rule" which applies only to wells that:

1. Are used only for domestic purposes;
2. Were drilled and completed on or after August 14, 2003;
3. Are not in an area in which a water supplier has a valid certificate of convenience and necessity (CCN) to service the area, unless that water supplier is not readily able to supply water;
4. Have a requested annual pumpage that does not exceed 500,000 gallons per household; and
5. Have a requested volume that does not exceed acceptable standards for both domestic use and landscape irrigation.

NDU wells are required to have water meters and the owners must periodically report water use. Presently, no water use fee is charged for NDU wells for water withdrawals, but the District does charge their users a small, one-time administrative permit application fee. As of the end of fiscal year 2013, approximately 77 NDU wells were in the District (Table 4-2).

4.1.1.2.2 Other Nonexempt Wells and Users

Most other nonexempt wells not authorized by general permits are required to have individual production permits from the District and to be metered; and owners/operators are required to pay an annual water use fee on the basis of their authorized use and to report actual water use monthly. In 2014, nonexempt well users paid water use fees ranging from $0.17 to $0.46 per

1,000 gallons of water used, depending on the type of permit (historical or conditional, as described in the following subsections). The District has about 90 individual production permit holders, not including NDUs. At the time of preparation of this HCP, an estimated 96 percent of all groundwater withdrawn in the District was by nonexempt wells.

These individually permitted wells are categorized by use type: agricultural, commercial, industrial, irrigation, and public water supply (Figure 4-1). The permittees include churches, office parks, quarry operations, schools, community athletic fields, golf courses, municipalities, and water-supply utilities. The largest use by far is for public water supply. Type of use is one determinant of the provisions that the District Board considers when it examines permittees' UCPs and UDCPs.

An example of a public water supply UDCP is the City of Buda's UDCP (http://tx-buda.civicplus.com/DocumentCenter/View/103). The City of Buda amended its UDCP in early 2012, as did other nonexempt permittees, to comply with 2011 amended requirements of the District's Rules and Bylaws, which called for enhanced curtailments or reductions of 40% of permitted pumpage during a District-declared Exceptional Stage Drought. The District amended its Rules again in October 2012, requiring even greater curtailment to 50% of permitted pumpage during a District-declared Emergency Response Period, to implement a prospective HCP measure and to achieve the newly established Desired Future Condition (DFC) of the Aquifer. All permittees will be required to amend their UDCPs again to accommodate the new 50% curtailment, which will become effective 2 years after the Rules were adopted; that is, October 11, 2015.

There are two primary types of individual production permits for nonexempt wells: Historical Production Permits, and Conditional Production Permits. Each type has different impacts on the habitats of the Covered Species.

Table 4-3: Mandatory curtailment of water withdrawals.

Curtailments established for different well permit types, aquifers, and drought conditions. (Curtailment expressed as percentage of authorized monthly water withdrawal in designated drought stage. For example, freshwater Edwards Aquifer historical permittees would be required to curtail their authorized monthly withdrawal by 30% during Stage III Critical Drought.)

Drought Curtailment Chart

Aquifer	Edwards Aquifer						Trinity Aquifer			
Management Zone	Eastern/Western Freshwater					Saline	Lower	Middle	Upper	Outcrop
Permit Type	Historical	Conditional				Hist.	Hist.	Hist.	Hist.	Hist.
		Class A	Class B	Class C	Class D					
Drought Stages										
No Drought	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water Conservation (Voluntary)	10%	10%	10%	10%	10%	0%	10%	10%	10%	10%
Stage II Alarm	20%	20%	50%	100%	100%	0%	20%	20%	20%	20%
Stage III Critical	30%	30%	75%	100%	100%	0%	30%	30%	30%	30%
Stage IV Exceptional	40%	50%[1]	100%	100%	100%	0%	30%	30%	30%	30%
Emergency Response Period	50%[3]	>50%[2]	100%	100%	100%	0%	30%	30%	30%	30%

Percentages indicate the curtailed volumes required during specific stages of drought.

1 Only applicable to NDUs and existing unpermitted nonexempts after A to B reclassification triggered by Exceptional Stage declaration

2 Curtailment > 50% subject to Board discretion

3 ERP (50%) curtailments become effective October 11, 2015. ERP curtailments to be measured as rolling 90-day average after first three months of declared ERP.

Wells with Historical Production Permits
Withdrawals from existing wells that were nonexempt and registered with the District as of September 9, 2004, were designated with Historical-use Status and authorized under permits designated as Historical Production Permits. Most of the authorized withdrawals from the Aquifer are authorized under such permits. Withdrawals under Historical Permits are required to curtail monthly pumpage by 20, 30, and 40 percent during Stage II-Alarm, Stage III-Critical, and Stage IV-Exceptional Droughts, respectively, and after October 11, 2015, by 50% during a Board-declared Emergency Response Period (These groundwater drought status terms are defined and discussed in Appendix D, and the curtailment program is summarized in Table 4-2). Historical Permits amended after September 9, 2004, to increase authorized withdrawals, and all new production permits after that date, are subject to Conditional Production permitting rules for the increase.

Wells with Conditional Production Permits
Withdrawals from wells that received initial permits or existing Historical Permits that have been amended to increase authorized withdrawals after September 9, 2004, were authorized under permits designated as Conditional Production Permits. This date was established by the Board following the findings and conclusions of the District's Sustainable Yield Study (Section, 3.2.2.1.2, Sources and Implications of Variation in Springflow at Barton Springs). The distinction from Historical Production Permits is important, because unlike those permits, withdrawals under Conditional Production Permits are authorized by the District only on an interruptible-supply basis. That is, the water supply under that permit is authorized only on the condition that the allowed monthly withdrawals will be increasingly curtailed during prolonged groundwater drought, up to and including complete cessation of pumping during Extreme Drought (Table 4-2). These permits have UDCPs that provide for mandatory curtailments of 50, 75, or 100 percent of their authorized monthly withdrawals during deepening stages of declared droughts. The District has further categorized Conditional Permits by whether they initially existed or were in process on April 27, 2007 (Class A Conditional Permits), or after that date but before March 24, 2011 (Class B Conditional Permits), or on or after March 24, 2011 (Class C Conditional Permits). A fourth conditional-use category, Class D, is reserved for use in supplying water from the Aquifer to future aquifer storage and recovery facilities, but only during non-drought periods. Class B, C, and D Conditional Permits have an accelerated curtailment schedule during drought. Certain Class A permits (generally those with access to alternate supplies) will be permanently converted to Class B permits upon declaration of a Stage IV-Exceptional Drought. All conditional production wells are expected under their permit terms to have ceased pumping during Stage IV-Exceptional Drought or deeper drought, which is the drought condition that is of most concern to the sustainability of the Covered Species.

4.1.2 Historical Perspective of Covered Activities

4.1.2.1 Evolution of Regulatory Program

The drought of the 1950s has become the basis for long-term water-resource planning in most of Central Texas. This drought of record (DOR) signified that both surface-water and groundwater management programs needed to incorporate drought management as a principal goal. In the ITP Area, the DOR produced the lowest recorded flows at Barton Springs, with the lowest measured daily flow of 9.6 cfs and the lowest monthly mean flow of 11 cfs. At that time, most water supplies in the area came from surface water. The USGS estimated that average groundwater use of the Barton Springs segment of the Edwards Aquifer then was only 0.66 cfs (Slade et al., 1986). So the lowest total monthly mean discharge from the Aquifer during the DOR was about 11.7 cfs.

But the area has grown rapidly since then and much new development was beyond the reach of centralized surface water-supply systems of the COA or the Lower Colorado River Authority (LCRA). The Aquifer provided a readily accessible, high-quality, and cheap source of water for the area, and its use by individual residential users, developments, and small suburban cities increased rapidly. But there was no authority that could implement a drought management program that could protect the water levels in the Aquifer or the springflow at Barton Springs.

When the District was formed in 1987, there was no restriction of any kind on withdrawals from the Aquifer or any other groundwater in the region. In fact, it was concern over that fact that led to the creation of the District. The District put into place its initial permitting program in 1989, which became fully implemented in 1990. This program was successfully used to identify and regulate withdrawals within the District, including notably a relatively novel drought management program with curtailments of as much as 20% of authorized withdrawals and based on declared drought stages (although those stages were then defined differently than now). But after a decade or so, withdrawals from the aquifer to serve the fast-growing area on the then southern fringe of Austin had increased to the point where the impact of withdrawals on Barton Springs during a recurrence of the DOR became a concern. The District undertook a study (Smith and Hunt, 2004) on the basis of the best science then available to ascertain the sustainable yield of the aquifer. Findings of the study indicated that during a recurrence of the DOR, authorized withdrawals, if un-curtailed, would cause yield problems with almost one-fifth of the wells in the District and Barton Springs flow would be reduced to near zero (Smith and Hunt, 2004).

These findings confirmed the need for changes in the District's regulatory and drought management program and, further, the need for more accelerated and larger curtailments. Awareness of the findings also marked the end of the first-generation groundwater management program that is denoted herein as the "pre-HCP program." Under that program, there was no upper limit on total withdrawals under permit, and drought curtailments were linked to percentiles of monthly flow at Barton Spring: no curtailment when flow was above the 50th percentile (51 cfs); 10% curtailment below the 50th percentile; 20% curtailment below the 25th percentile (30 cfs); and 30% curtailment at or below 10 cfs (which has only been reached during the DOR). In practice, little enforcement of these curtailment limits actually occurred, and the actual curtailments achieved then were likely considerably smaller while withdrawals grew steadily. A more effective drought management plan became a priority in the early 2000s.

The need for additional resources to help define the new drought management program and its ecological benefits led to several consultations with the U.S. Fish & Wildlife Service (Service) and eventually to the first HCP grant awarded to the District in 2004, marking the initial phase of the HCP. This work produced a more rigorous and meaningful drought trigger methodology and a more rigorous and stringent drought management program that was based on the imposition of a junior-senior permitting scheme that included conditional-use permits with interruptible production, as well as a preliminary integrated HCP and Environmental Impact Statement (EIS) document. Significant droughts in 2006, 2008–09, and 2011 provided the impetus for a series of amendments to the permit-based drought rules, such that the drought management program became one of, if not the most, stringent in the State. This regulatory program was developed under the Texas Open Meetings Act and in accordance with the statutory requirements for rulemaking, providing multiple opportunities for public and stakeholder input at each rulemaking step.

In the second phase of HCP development, pioneering experimental work concerning DO concentrations and salamander mortality (Poteet and Woods, 2007; Woods et al., 2010) was done. This work (Section 5.2.1, Experimental Assessment of Salamander Responses to Changes in Water Chemistry Related to Springflow), funded by the District HCP, strongly suggested that Barton Springs flow needed to be still higher during Extreme Drought; and therefore aggregate withdrawals needed to be less than what could be achieved under the then-current regulatory program. This result informed the District's 2010 recommendation to the Groundwater Management Area (GMA) 10 joint regional planning committee for a new, statutorily mandated set of groundwater planning objectives called Desired Future Conditions (DFC) of the Aquifer. A consensus of the GMA considered DFCs to be protective of the Aquifer, both as a water supply and as habitat for the Covered Species, and to be achievable (TWDB, (2014). The Aquifer now has two DFCs: (1) an effective upper limit on withdrawals of 16 cfs, to limit the acceleration of the onset of drought conditions in the Aquifer resulting from withdrawals; and (2) maintenance of springflow not less than 6.5 cfs during a recurrence of DOR conditions. Using the lowest total monthly discharge (springflow and a small amount of pumpage) reported during the DOR, 11.7 cfs, for reference, total withdrawals from all wells in the Aquifer during a recurrence of DOR conditions need to be no more than 5.2 cfs on an average annual basis to achieve those DFCs.[12] The District's then-current (2012) regulatory program, which was developed after numerous informative consultations with other advisory groups and stakeholders, could produce a minimum of 6.7 cfs of pumping, rather than the 5.2 cfs needed.

The 1.5 cfs "gap," which is the difference between the modeled maximum 5.2 cfs of average annual pumping allowed during DOR conditions (MAG for the DOR DFC) and the 6.7 cfs authorized under the regulatory-mandated curtailment program in early 2012, was addressed in a stakeholder process. That process culminated in late 2012 with phased measures that were incorporated or were to be incorporated into the current (2014) regulatory-based drought management program; and also with a commitment to promote the long-term development of alternative water supplies when and where feasible, and where such supplies would benefit management of the Aquifer during severe drought. The District anticipates that this level of curtailment, while very stringent, will be able to be achieved on an aggregate basis within the next 3 years; currently (2014) the gap has already been reduced to 0.5 cfs. Confidence that the gap will be completely closed is based on ongoing efforts to encourage the retirement of currently permitted historical withdrawals; new rules requiring higher levels of curtailment if a DOR-level drought should recur; new rules incentivizing higher curtailments during severe drought in exchange for proportional increases in permitted withdrawals during non-drought; historical experience with some permittees that voluntarily substitute available alternative supplies for authorized Aquifer withdrawals during severe drought; "right-sizing" provisions; as warranted, use of improved aquifer modeling to better account for all recharge sources, including urban recharge; and the District's and permittees' continuing efforts to develop

[12] The 5.2 cfs is the modeled available groundwater (MAG) which is the estimated maximum amount of annual withdrawals allowable while preserving the minimum Extreme Drought DFC of 6.5 cfs as determined by groundwater availability modeling.

and extend alternative supplies to historical-production permittees. Further, District hydrogeologists now consider it extremely unlikely that DOR conditions will reoccur before the 2015 implementation date of these measures. By then, the key new rules will become effective and enforceable and permittees will have had an opportunity to take advantage of substitution incentives. Additional alternative supplies may help assure that outcome, but that will depend on the commitments of individual permittees as much, if not more than the District. In aggregate, this DFC-based regulatory program/groundwater management scenario is designated the "HCP program."

Through full implementation of the measures described above, the gap of 0.5 cfs that currently remains is expected to be bridged by the issuance date of the ITP; and bridged with or without factoring in the difference between the authorized total pumpage used in calculating the gap and the smaller actual total pumpage that typically occurs. This difference has been noted even in severe droughts. As necessary and at the Board's discretion, some additional rulemaking and policy development, both currently undefined, as well as individual, stop-gap Board Orders may also be used, providing further assurance that the gap will be closed and the springflow-based DFC will be achieved in the future.

In 2011, the Texas Legislature passed Senate Bill 332, reinforcing the private property ownership of groundwater in place and also requiring that groundwater conservation be balanced by withdrawing the maximum amount of water feasible. Then the Texas judicial system issued two decisions, one by the Supreme Court in mid-2012 in *EAA v. Day* (369 S.W.3d 814 (Tex. 2012)) and another by the 4th Appellate Court in early 2013 in *EAA v. Bragg* (No. 04–11–00018, 2013 WL 5989430 (Tex. App.—San Antonio, November 13, 2013)), that held unequivocally the possibility of compensable regulatory takings by groundwater regulation, even if a groundwater conservation district (GCD) is acting fairly and within its authority and rules. These two cases and their implications for groundwater management are discussed in more detail in Section 7.2.1.7, Recent Texas Court Decisions and Aftermath.

4.1.2.2 Changes to Pre-HCP Baseline

Taken together, the internal and external developments in 2011–13 described in the preceding subsection indicate the District has about reached the practical limit of what it can legally and statutorily accomplish with its regulatory-based demand reduction program, without incurring potentially catastrophic legal and financial risks associated with compensable regulatory takings. The District considers the program as currently proposed to represent minimization and mitigation "to the maximum extent now practicable," subject to possible future changes via statutory and adaptive management processes. The Service will consider and determine what is practicable in its Findings documentation as part of its intra-Service consultation process.

The beneficial effect of the District's drought-management regulatory program on springflow is shown in Figure 4-2. The figure shows computed Barton Springs flow for current (2014) nonexempt withdrawals authorized by the District (11.6 cfs) and as regulated alternatively by the two groundwater management scenarios; that is, before and after HCP measures were in place. The figure also shows the springflow that would have existed during the period of record with only the small amount of unregulated groundwater withdrawals from exempt wells, designated as the "exempt-only pumping" scenario. The springflow of the exempt-only pumping scenario (which includes the DOR) excludes the effects of nonexempt withdrawals that actually occurred each month during the period of record. The springflow of the exempt-only pumping scenario is the baseline for comparison in this HCP. The springflow of the pre-HCP scenario in Figure 4-2 shows how the baseline springflow would have changed by regulating permitted withdrawals with only the curtailment program as it existed before 2004, when the District's conditional permitting program was instituted and the HCP development project was initiated. (At that time, there was 10.2 cfs of authorized-nonexempt use; with 0.45 cfs of exempt use, total withdrawals were about 10.6 cfs). The springflow of the HCP scenario in Figure 4-2 reflects a regulatory program with the full complement of proposed HCP measures in place.

To facilitate comparison, both the pre-HCP and the HCP scenarios in Figure 4-2 are applied to the same rate of withdrawal, that is, 11.6 cfs, the 2014 total permitted in 2014 (including both historical and conditional withdrawals). Each of those scenarios restricts withdrawals during drought in different ways and to different degrees, which in turn affects springflow differently. However there is another important distinction between the two scenarios that is not reflected in the springflow hydrograph of Figure 4-2. The two scenarios would place substantially different management restrictions on total withdrawals from the Aquifer that ultimately could be authorized in the future.

In the pre-HCP scenario, there is essentially no upper limit on the amount of water that could be authorized to be withdrawn from the Aquifer to meet demand, which would accelerate the onset of drought conditions in the Aquifer and reduce springflow even further during future droughts even with the pre-HCP curtailments. For example, Scanlon et al. (2001) indicated that by 2050, unregulated Aquifer use would increase to 210% of what it was in 2000, or about 19.6 cfs without effective limitation, even during a DOR recurrence. Without the District's current and proposed regulatory program, the increase in *total* pumpage from the Aquifer would have continued to be largely unchecked during the course of the ITP.

The proposed HCP program provides a regulatory mechanism to restrict the total amount of water authorized to be withdrawn from the Aquifer in the future, while providing for increased use of the Aquifer only during non-drought conditions. Only the proposed HCP program's management scheme has an upper limit on authorized withdrawals, at 16 cfs, which has been established by the District Board to allow an acceptable level of acceleration into drought; that is, approximately 1 month. In other words, a 16-cfs upper limit on withdrawals would ensure that the Aquifer reaches drought conditions no sooner than one month earlier than otherwise. The pre-HCP program imposes no such cap. Only the HCP program differentiates authorized conditional pumpage (pumpage greater than 10.2 cfs) from authorized historical pumpage (pumpage up to 10.2 cfs). Conditional pumpage is interruptible and subject to accelerated curtailment up to and including complete curtailment. Historical pumpage is not interruptible but subject to curtailment that provides a minimum firm-yield supply during Extreme Drought. Thus, the proposed HCP program has an assured regulatory limit on all pumpage to no more than 5.2 cfs (including 0.5 cfs of exempt use) during a DOR recurrence. The pre-HCP program does not. These differences mean that the springflow shown in Figure 4-2 under the HCP Scenario does not depend on what additional total

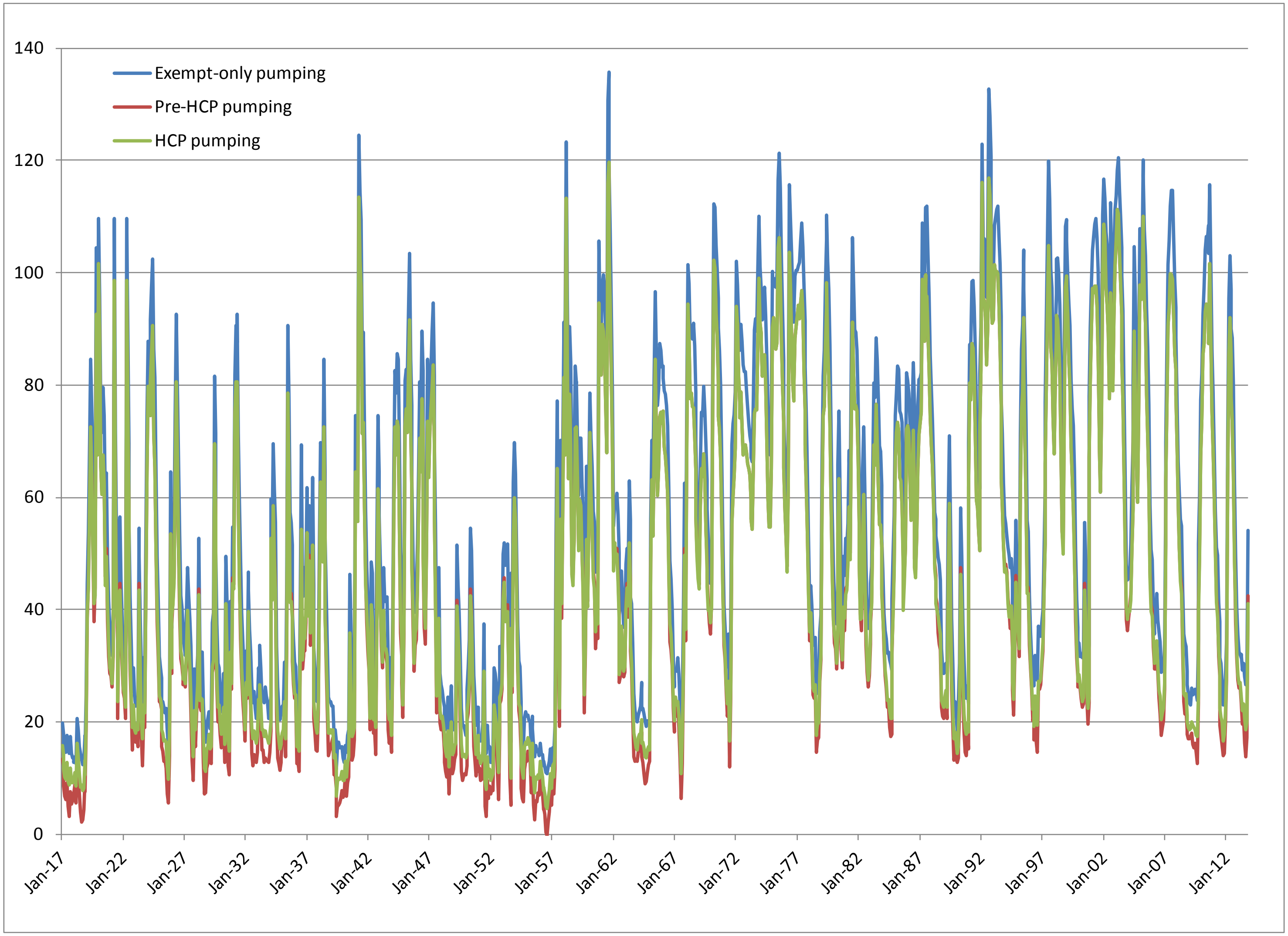


Figure 4-2: Computed Barton Springs flow, 1917–2013, under conditions of exempt-only pumping, pre-Habitat Conservation Plan, and Habitat Conservation Plan pumping.

Computed springflow showing the effects of two groundwater management scenarios relative to springflow that would have existed with only withdrawals from exempt wells**.** The HCP management scenario is more effective than the pre-HCP management scenario in preserving springflow under low-flow conditions, when the Covered Species are most stressed by severe drought.

pumpage is authorized, while the springflow under the pre-HCP Scenario may be further reduced from that shown in the figure, especially during severe drought.

4.1.3 Statutory and Regulatory Authorities for Covered Activities and Integrated Conservation Measures

The District's statutory authority and purpose are to preserve, conserve, and protect the groundwater resources of the District. A principal dimension in meeting this legislative charge is implementation of a regulatory program to manage the withdrawal of groundwater from the Aquifer during both drought and non-drought conditions. The District HCP relies on this authority, as elaborated in this section.

The powers vested in the District stem from the laws enacted by the State of Texas, namely Senate Bill 988, 70th Regular Session, the District's enabling legislation now codified in the Special District Local Laws Code, Chapter 8802, Barton Springs/Edwards Aquifer Conservation District; and the Texas Water Code, Chapter 36. Chapter 36 is the over-arching statutory authority for virtually all GCDs in Texas.

Except as specifically altered by the supervening statutory authority of enabling legislation, Chapter 36 establishes how groundwater is managed and administered by GCDs. Additional and revised authorities and requirements affecting the District were enacted by the Texas Legislature in Senate Bill 1212 (71st Session), Senate Bill 1 (75th Session), Senate Bill 2 (77th Session), House Bill 1763 (79th Session), Senate Bill 3 (80th Session), Senate Bill 747 (80th Session), and Senate Bill 433 (82nd Session). A listing of these bills with a brief summary description is provided in Table 4-4.

Table 4-4: Legislation affecting groundwater conservation districts and District authority.

Year	Bill No.	Caption
1987	SB 988	Related to validating the creation of the Barton Springs/Edwards Aquifer Conservation District and amending the powers and duties of that district; providing the authority to impose penalties and water use fees; and reducing the authorized level of taxation.
1989	SB 1212	Relating to the creation, administration, and operation of underground water conservation districts and of management and critical areas.
1997	SB 1	Relating to the development and management of the water resources of the State; providing penalties. (aka the "omnibus water bill")
2001	SB 2	Relating to the development and management of the water resources of the State, including the ratification of the creation of certain groundwater conservation districts; providing penalties.
2005	HB 1763	Relating to the notice, hearing, rulemaking, and permitting procedures for groundwater conservation districts. (was expanded to include groundwater planning provisions).
2007	SB 3	Relating to the development, management, and preservation of the water resources of the State; providing penalties.

2007	SB 747	Relating to the authority of the Barton Springs/Edwards Aquifer Conservation District to charge certain fees and limit groundwater withdrawals during a drought.
2011	SB 433	Relating to the de-annexation of land in Bastrop County by the Barton Springs/Edwards Aquifer Conservation District.

The District is governed by a five-member Board of Directors elected by the voters in five single-member precincts (Figure 4-3.) The internal precinct boundaries may change through redistricting with any change in the external boundaries or with each decennial census. Upon decennial redistricting, the Board shall place no more than two of the precincts entirely within the full-purpose boundaries of the COA, as the boundaries exist at that time. Such redistricting is a normal, expected part of the District's governance and changes in director precinct boundaries are neither Changed Circumstances under the HCP nor proposed to require ITP amendment. Each elected Board ensures the management and policies of the District, including its groundwater management program, are aligned with local interests and are sworn to comply with all applicable federal, state, and local laws, which will include the prospective ITP and HCP.

Under its statutory powers, the District's Board has adopted and from time to time amends a set of Rules and Bylaws (BSEACD, 2012), under which it has registered all known wells and has permitted those certain wells that are subject to its jurisdiction and are not exempted from permitting by law or rule. Rule changes that support or are otherwise not inconsistent with the biological goals and objectives of the District HCP in Section 6.1, Biological Goals and Objectives of HCP, are also proposed to be neither Changed Circumstances nor a requirement for an amended ITP. Important to the success of the HCP is the fact that most (approximately 95%) of the groundwater withdrawn from the Aquifer is nonexempt and therefore actively managed under District permit authorizations.

The withdrawal limits now imposed on wells in the District have been adopted and implemented in an effort to protect groundwater resources and reduce drought-stage groundwater withdrawals, to sustain water supplies for its permittees, and to maintain springflow at Barton Springs, to the maximum achievable extent, subject to the limits of reasonable regulation and legal liability. The most current set of Rules and Bylaws pertaining to Barton Springs flow are on the District's website under the tabbed menu heading, "About Us/Governing Documents" (http://www.bseacd.org/about-us/governing-documents/). Information on the permitting program and other regulations applicable to the Barton Springs segment of the Edwards Aquifer is under the "Regulatory Program" menu (http://www.bseacd.org/regulatory/).

The Rules and Bylaws are adopted in accordance with the District Management Plan (BSEACD, 2013), which is reviewed, revised as warranted, and readopted at least every 5 years. It was most recently amended and adopted by Board Resolution on September 27, 2012, and approved by the TWDB on January 7, 2013. (The Management Plan, in turn, is prepared in accordance with Texas Water Code, Chapter 36, Section 1071, and TWDB requirements under Texas Administrative Code, Chapter 356, Sections 5 and 6.)

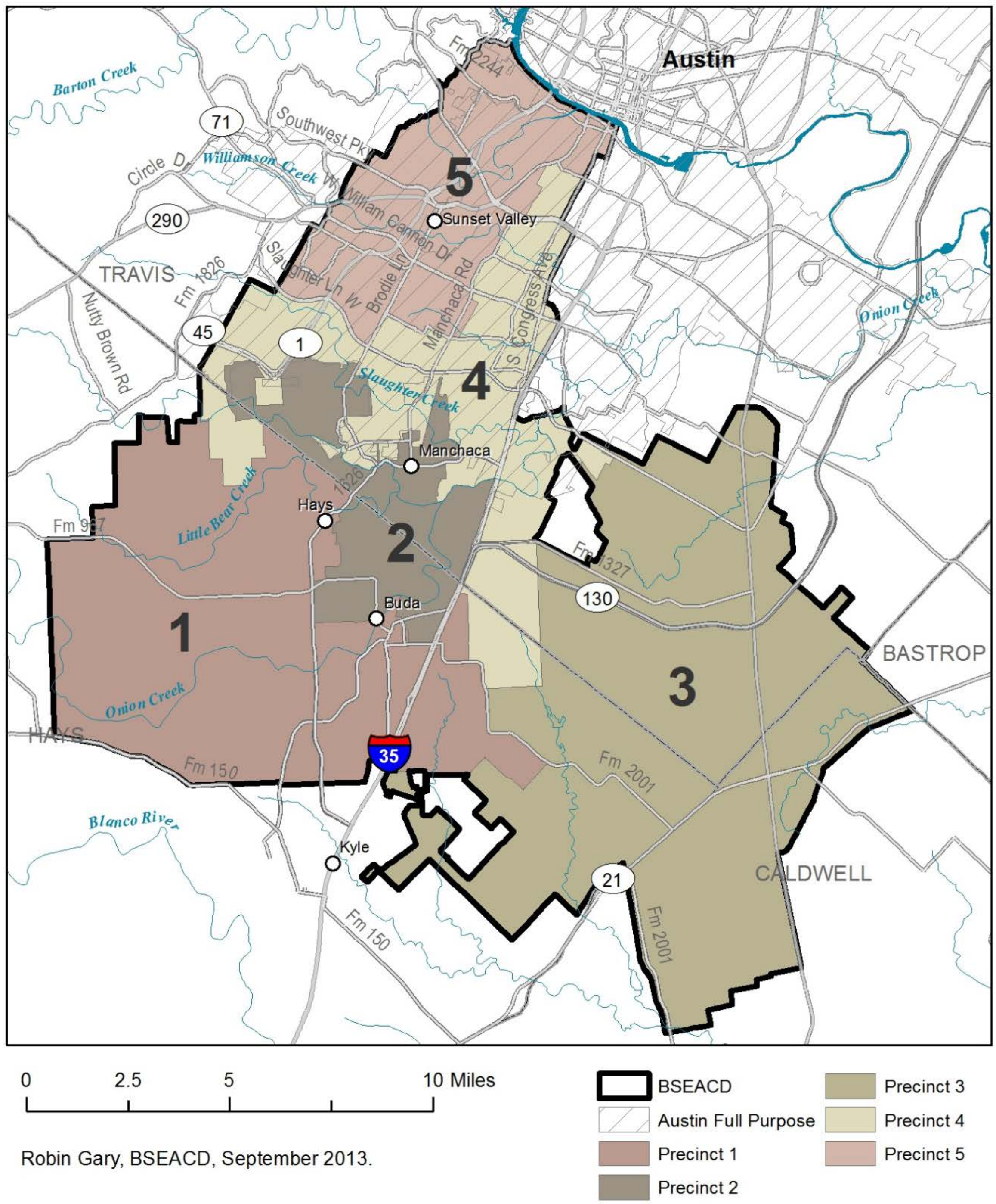


Figure 4-3: Barton Springs/Edwards Aquifer Conservation District director precinct boundaries. Board members are elected by popular vote of all residents within their single-member precincts.

The District's authority mainly relates to groundwater quantity; it has only limited and indirect authority to protect groundwater quality. Its ability to offer such protection derives primarily from its authority to avoid and minimize waste of groundwater, which by definition includes contamination or pollution of water that is within or recharges the Aquifer and that harmfully alters the character of the groundwater. GCD regulation to prevent the harmful alteration of groundwater more typically involves the prevention of pollution through the enforcement of well construction standards and setback distances from potential sources of contamination. The District does not have the explicit authority under its enabling legislation to regulate land use, including subdivision restrictions.

As a practical matter, most groundwater quality protective measures are afforded by other regulatory entities with more explicit authority to regulate land-use activities, even for groundwater within the District's jurisdictional area. The programs and entities that are involved in groundwater quality protection are discussed in Appendix H.

4.1.4 Public Participation in Developing Covered Activities and Integral Conservation Measures

As a political subdivision of the State of Texas, the District is obligated to operate transparently and to routinely involve the public in its normal business operations, with only a few statutorily prescribed exceptions. Further, the "Five Point Policy" developed by the Service as recommendations and guidance in developing HCPs prescribes "opportunities for public participation" as one of the five elements.

During the period in which this HCP was being developed, the District held more than 80 Board meetings, including work sessions, in which the HCP was specifically identified as a discussion item on the agenda. These were all public meetings under the Texas Open Meetings Act, with agendas posted with the Texas Secretary of State (until September 2011), at county courthouse bulletin boards, and at the District office typically 6 days (and no less than 3 days) in advance of the meeting. With few exceptions, all of these Board meetings offered opportunity for public comment and participation as desired on the ongoing HCP evolutionary process, including consideration of both the regulatory program and the proposed conservation measures, and their documentation. The HCP has had a page on the District website since 2007, which has been used as a communication vehicle for HCP project progress and documentation.

The District has provided additional opportunities for structured participation by stakeholders and the public, and it has considered perspectives of other knowledgeable members of the scientific community in developing the HCP:

- During the active investigation and development stages of the HCP, the District used from time to time several external advisory groups to assist the District's efforts, including:

  a. A hydrogeological/technical advisory committee, in the evaluation of aquifer drought management options and drought trigger methodologies;
  b. A biological/technical advisory committee, in the planning and monitoring of needed research on stressor-responses, the effectiveness of potential conservation measures, and the assessment of residual harm to salamander organisms and populations;

c. Two topical stakeholder advisory committees on the efficacy of (1) options for stringent conservation measures that would take effect during Exceptional and Extreme Droughts, and (2) options for the District to promote development and use of alternative water supplies; and
d. A public/stakeholder advisory committee, in determining the scope of the HCP, recommending possible avoidance, minimization, and mitigation measures, providing a forum for public discourse on HCP development and progress, and building consensus where possible.

Each advisory group met many times during the course of HCP development, and nearly all meetings, which typically were attended by one or more District directors as well as staff, were posted as Texas Open Meetings, with publicized agendas and were open to the public at-large.

- In the latter stages of HCP development and documentation, the District voluntarily established, used, and intends to continue to use, a standing Management Advisory Committee (MAC) of experts, stakeholders, and private citizens. The MAC provides independent initial reviews and annual assessments of the HCP and the progress being made toward HCP goals, identifies and evaluates additional minimization and mitigation measures or modifications to existing goals that appear warranted, and makes appropriate recommendations to the District Board on a periodic basis. This MAC is an integral part of the District's continuous improvement process and adaptive management.

The MAC was formed by the Board in February 2013. Its functions are characterized and its members are identified in Section 6.5.1.2, District Management Advisory Committee. In effect, the MAC is the continuing advisory vehicle for the previous advisory groups, and many of the MAC members participated in one or more of those previous advisory groups during active development of the HCP. In addition to their prospective involvement in the annual review and reporting process, the District used MAC members to review and comment on preliminary drafts of the HCP before it was submitted as part of the ITP application; and continues to use MAC members to help the District (and the Service) respond to public and agency comments on the HCP and to ensure that responses address stakeholder and public needs. The MAC meetings are also posted as Open Meetings to encourage public participation.

4.2 Requested Permit Duration

The proposed ITP for the District would be issued for a term of 20 years and be renewable thereafter, subject to administrative procedures existent at that time. Local, regional and state water-resource planning entities in Texas are mandated to use a 50-year time horizon for almost all water-resource planning functions, ranging from the establishment of DFCs of a groundwater reservoir managed by a GCD, including the Aquifer, to the regional and statewide water-resource planning programs of the TWDB. Water-supply strategies are required to supplement the firm-yield supply available during a recurrence of the DOR within that planning horizon. In the HCP Planning Area, the DOR is the decade-long drought during 1947–56 (using the District's drought trigger definitions discussed in Section 4.1.1.2, Nonexempt Wells and Users). Cleaveland et al. (2011) used tree-ring data and analysis to estimate that a decadal drought like the DOR has a recurrence interval in the

HCP Planning Area of about 100 years. The effects of climate change are just now beginning to be understood, especially at the regional level, but it is already clear that they may have a profound impact on drought management imperatives over a shorter period. The effects of climate change may be particularly important to the habitat of the Covered Species, which suggests the advisability of a shorter permit term. A term of 20 years represents a rational balance between the factors of long-term DOR recurrence and likely shorter-term climate change.

The groundwater management plans, regulatory strategies, and tactical measures used by water-resource management agencies like the District are continuing functions, requiring periodic updating through the course of long-term planning horizons. As specified in Sections 6.3.2, General Performance Metrics and Reporting; 6.4, District HCP Adaptive Management Process; and 6.5.1, [Implementation Responsibility of] Barton Springs/Edwards Aquifer Conservation District, the measures to be implemented by the District to minimize or mitigate the impacts of take will be reviewed periodically throughout the term of the ITP and beyond. Because the ITP depends on a continuing groundwater management program to provide most of the HCP conservation measures, it is the District's intent to apply for renewal of an ITP, amended as appropriate, near the end of the initial term.

5.0 Analysis of Impacts Likely to Result from Taking

5.1 Covered Species

This HCP proposes incidental take coverage for two endangered species, Barton Springs salamander (*Eurycea sosorum*), federally listed as endangered in 1997; and Austin blind salamander (*E. waterlooensis*), federally listed as endangered in 2013. Both species are known only from the springs and outlets of the Barton Springs complex of the Edwards Aquifer. This section describes each species and provides information on life history, distribution, threats and reasons for decline, and the survival needs for each species in individual descriptive subsections. Section 5.2, Effects of Take on Covered Species, assesses taking of these Covered Species by the Covered Activities and its consequences.

The descriptions that follow draw from several sources compiled by biologists with expertise in the Covered Species, especially the Barton Springs salamander—its life history, population characteristics, habitat, and the influences that may cause incidental take. Three of the principal sources referred to in this section are the Barton Springs Salamander Recovery Plan (Service, 2005); the U.S. Fish & Wildlife Service (Service) final rule that listed the Austin blind salamander (Service, 2013b); and the COA Barton Springs Pool HCP (City of Austin, 2013). Citations to the principal and other sources are made where warranted.

5.1.1 Species Descriptions and Life Histories

5.1.1.1 Barton Springs Salamander

The Barton Springs salamander (Figure 5-1) is a member of the Family Plethodontidae (lungless salamanders). Texas species within the genus *Eurycea* inhabit springs, spring runs, and water-bearing karst formations of the Edwards Aquifer (Chippindale et al., 1993). They are aquatic and neotenic; that is, they retain larval, gill-breathing features throughout their lives and do not undergo metamorphosis and leave water. Instead, they live in water throughout their life cycle where they mature and reproduce. The species was first collected from Barton Springs in 1946 (Brown, 1950, Texas Natural History Collection specimens 6317–21) and formally described in 1993 (Chippindale et al.). This species has been a continuing focus of various studies by the biologists of the COA Watershed Protection Department for more than a dozen years. Studies have been done both in the field around the spring outlets and in the specialized salamander laboratory/refugium operated by the COA. Documentation of most of these studies is in the Barton Springs Pool HCP (City of Austin, 2013).

Figure 5-1: (Above) Barton Springs salamander, *Eurycea sosorum*; (below) Austin blind salamander, *E. waterlooensis*.
Photo credit: City of Austin, Watershed Protection Dept.

Adults are about 2.5 to 3 inches (63–76 mm) long. The coloration on the adult salamander's upper body varies from light to dark brown, purple, reddish brown, yellowish cream, or orange. The characteristic mottled salt-and-pepper color pattern on the upper body surface is due to brown or black melanophores (cells containing pigments called melanin) and silvery-white iridiophores (cells containing pigments called guanine) in the skin. On either side of the base of the head is a set of three feathery gills that are bright red (Service, 2005).

Juveniles closely resemble adults (Chippindale et al., 1993). Newly hatched larvae are about 0.5 inch (12 mm) long and may lack fully developed limbs or pigment (Chamberlain and O'Donnell, 2003).

The Barton Springs salamander is more closely related to the San Marcos salamander than to either the Austin blind or Texas blind salamanders (Hillis et al., 2001). The Barton Springs salamander is carnivorous and appears to be an opportunistic predator. Known prey include ostracods, chironomids, copepods, mayfly larvae, amphipods, oligochaetes, and planarians (Chippindale et al., 1993; Gillispie, 2011). An analysis of the gastro-intestinal tracts of 18 adult and juvenile Barton Springs salamanders and fecal pellets from 11 adult salamanders collected from Eliza Spring, Barton Springs Pool, and Old Mill Spring most commonly contained ostracods, amphipods, and chironomids (City of Austin, 2013).

Gravid females, eggs, and larvae of Barton Springs salamander are typically found at different times of the year in Barton Springs, which suggests that the salamander can reproduce year-round (Hillis et al., 2001); although generally they are not observed with the same frequency during drought periods. The eggs hatch in 3–4 weeks. Hatchlings are about one-half inch long (snout to tip of tail), often still with yolk sacs and limb buds. Juvenile Barton Springs salamander become sexually mature at about 11 months (43–50 mm long) (City of Austin, 2013). In captivity, Barton Springs salamander has been observed reproducing to an age of at least 8 years (City of Austin, 2013). The representativeness of such characteristics in the field is not well established.

Observations of courtship among captive pairs of Barton Springs salamanders (Chamberlain and O'Donnell, 2003) are consistent with Arnold's (1977) description of the tail-straddling walk, which is a behavior unique to plethodontid salamanders (Service, 2005). Females of some salamander species may store sperm for as long as 2.5 years before ovulation and fertilization occur (Duellman and Treub, 1986). In 2001, a captive Barton Springs salamander female laid viable eggs 1 month after being isolated, which indicates that females of this species can store sperm for at least this length of time (Chamberlain and O'Donnell, 2003).

Since the COA began surveying salamanders in 1993, very few eggs have been found in the field. The first egg was found detached near a spring orifice in Old Mill Spring in May 2002. The other three eggs were found near spring orifices in Barton Springs Pool (December 2002, May and August 2003) (Dee Ann Chamberlain, City of Austin, personal communication, 2003). It is hypothesized that the Covered Species lay their eggs in the aquifer below the surface because only a few eggs have been found in the field. Hatching of eggs in captivity has occurred within 16 to 39 days after eggs have been laid (Chamberlain and O'Donnell, 2003). Hatching success in captive Barton Springs salamanders may be highly variable as indicated by hatching rates of 0 to 100 percent that have been reported by the COA (Chamberlain and O'Donnell, 2002, 2003). Egg mortality has been attributed to fungus, hydra (small invertebrates with stinging tentacles), and other possible factors such as infertility (Service, 2005).

Eggs are laid by female salamanders one at a time and receive no parental care. Although a female can lay a single egg in minutes, the entire egg-laying event may take several hours, depending on clutch size (Chamberlain and O'Donnell, 2003). Biologists associated with the COA captive breeding program have observed clutch sizes ranging from 5 to 39 eggs with an average of 22 eggs on the basis of 32 clutches (Chamberlain and O'Donnell, City of Austin, unpublished data, 2003).

The first 3 months following hatching is a critical period for juvenile survival (Chamberlain and O'Donnell, 2003). Newly hatched larvae have a yolk sac to sustain their nutritional needs in the early days after hatching. Larvae feeding on prey have been observed 11 and 15 days after hatching (Lynn Ables, Dallas Aquarium, personal communication, 1999). Although reproduction has occurred in captivity, it has been sporadic. No consistent methods or techniques have been found to enhance egg production (Service, 2005).

At times, females have held eggs for more than a year before the eggs are either laid or reabsorbed. COA biologists believe that stable environmental conditions, water quality, adequate space, habitat diversity, and food availability may influence egg laying (Chamberlain and O'Donnell, 2003). Rough surfaces (not smooth like glass) may facilitate successful spermatophore (sperm mass) deposition and transfer (Service, 2005).

The life span of the Barton Springs salamander in the field is unknown. Assuming that collected salamanders were at least 1 year old when collected, reported longevity for individual Barton Springs salamanders in captivity is at least 15 years (City of Austin, 2013).

Other than gas-bubble trauma (Service, 2005, Section 1.6), only a few physiological anomalies have been reported in the field for the Barton Springs salamander. They include an infection of one male adult and possibly one gravid female with immature trematodes (Chamberlain and O'Donnell, 2002), an unknown myxosporidian parasite, and bacteria in the genera of *Aeromonas* and *Pseudomonas* that have affected salamanders in captivity (Chamberlain and O'Donnell, 2003). It is not known whether these pathogens are present in the spring habitats of the salamanders or what threat they may pose to salamanders in the field (Service, 2005).

Predation on Barton Springs salamanders in the field is probably minimal when adequate cover is available for salamanders to hide from predators. Most but not all potential predators of the salamander that are native to the Barton Springs ecosystem are opportunistic feeders (Service, 2013). Crayfish (*Procambarus* sp.) and other large predatory invertebrates may prey on salamanders or salamander larvae and eggs (Gamradt and Kats, 1996). Predatory fish found at Barton Springs include mosquitofish (*Gambusia affiinis*), longear sunfish (*Lepomis megalotis*), and largemouth bass (*Micropterus salmoides*). Mexican tetras are non-native fish and are aggressive generalist predators that are occasionally found in Barton Creek, Barton Springs Pool, Upper Barton Spring, and Old Mill Spring (Service. 2005). They are reasonably inferred to be potential predators, but no observations of such predation on the salamander have been reported.

The COA (2013) also reports that the two *Eurycea* species at Barton Springs may opportunistically prey on one another.

The sex, age, and number of individuals of the Barton Springs salamander are not precisely known because the population is believed to be small and the habitat is underwater and from time to time underground; so some habitat is inaccessible under any circumstances, making a complete population census impossible. As mentioned, the population size varies more or less repetitively but not regularly, typically in response to natural variations in resources and environmental conditions. Over the long term, statistical trends can be inferred from the exhaustive and extensive censuses of observable individuals that are being conducted by the COA, in association with recorded variations in climate, springflow, DO concentration, and other relevant factors that influence habitat (City of Austin, 2013, 2007b).

5.1.1.2 Austin Blind Salamander

The Austin blind salamander was formally described by Hillis et al. (2001). The Service provides a comprehensive description of this species and its ecological requirements in its recent listing rule (Service, 2013b), which is incorporated by reference into this section.

The Austin blind salamander (Figure 5-1) is also a member of the Family Plethodontidae (lungless salamanders), one of the several Texas species within the genus *Eurycea* that inhabit springs, spring runs, and water-bearing karst formations of the Edwards Aquifer (Chippindale et al., 1993). It is closely related to the Texas blind salamander (*Eurycea* [formerly *Typhlomolge*] *rathbuni*), which is found in the San Antonio segment of the Edwards Aquifer in San Marcos (Hillis et al,. 2001).

The Austin blind salamander averages about 2 inches long (EARIP HCP, 2012), slightly smaller than the Barton Springs salamander. Other physical characteristics that distinguish the Austin blind salamander from the Barton Springs salamander include eyespots covered by skin instead of image-forming lenses, an extended snout, fewer costal (upper body) grooves, and pale to dark lavender coloration (Hillis et al., 2001). In June 2001, the Austin blind salamander was designated a candidate for listing as endangered or threatened (Service, 2005). The species was listed as endangered on August 20, 2013 (Service, 2013b).

The Austin blind salamander is also carnivorous and appears to be an opportunistic predator. There is evidence of partial overlap in diet composition and egg deposition sites of the Covered Species, which has been interpreted as indicative of natural selection for ecological niche-partitioning (different patterns of resource use) to reduce competition (Vrijenhoek, 1979; Pianka, 2000). Austin blind salamander is believed to feed mostly on blind amphipods and isopods found within the aquifer; but when they are at the surface of the springs, they also will consume other small invertebrates (City of Austin, 2013). These factors can maintain genetic divergence between the Covered Species (Paterson, 1985).

The uncertainties and limitations of surveying to determine the sex, age, and number of individuals of the Austin blind salamander are not precisely known because the population is believed to be small and the dominant habitat is subterranean (underground) and aquatic (Hillis et al., 2001). So most of its habitat is inaccessible under any circumstances, which makes surveying of the species unreliable. Accordingly, less is known about the sex, age, and number of individuals—and therefore life-cycle characteristics—for Austin blind salamander than for Barton Springs salamander.

5.1.2 Species Distribution

5.1.2.1 Barton Springs Salamander

Both species are observed in the vicinity of the spring outlets, although the epigean Barton Springs salamander is more likely to be found at and near submerged rock ledges and gravelly areas. After the COA completes the spring-run restoration as part of the Barton Springs Pool HCP (City of Austin, 2013), the re-aerated water of the spring run typically will have larger DO concentration than that of the water issuing from the outlets, especially during low-flow conditions. This is important, in that some researchers (for example, Turner, 2007) have suggested the salamanders appear to be able to migrate locally to areas of less stress (higher flow, higher water velocity, larger DO concentration, more prey, fewer predators) in the Aquifer and in spring runs during periods of even moderate drought. No Critical Habitat has been designated by the Service for the Barton Springs salamander.

5.1.2.2 Austin Blind Salamander

The Austin blind salamander is sympatric with (occurs in the same or substantially overlapping range with) the Barton Springs salamander, probably incidentally in the epigean environment on the basis of its morphology (form and structure). The Critical Habitat for Austin blind salamander, as designated by the Service (2013b), is shown in Figure 5-2. Its range away from the spring outlets is in the subsurface, within the Aquifer, and is largely inferred from ranges reported for other similar species (Service, 2013b). Its presence and migration away from the spring outlets are implied by the Critical Habitat designation to contribute to assuring the redundancy, representation, and resilience of the Austin blind salamander (Service, 2013a). Hillis et al. (2001) also notes its ability to migrate locally to areas of reduced stress, as does the Barton Springs salamander. However, currently (2014) no data suggest how far afield within the Critical Habitat Area, in the subterranean region away from the outlets, the organisms migrate or have migrated. Unlike Barton Springs salamander, Austin blind salamander has not been regularly observed at the non-perennial Upper Barton Spring. The hydrogeologic setting suggests the subterranean habitat near the outlets is a complex, three-dimensional network of solution-enlarged openings; and because Barton Springs complex flow issues from both confined and unconfined parts of the Aquifer (Hauwert et al., 2004), different DO characteristics likely exist in the nearby subterranean environment (Lazo-Herencia et al., 2011). Although both species have been observed in the vicinity of the spring outlets (other than Upper Barton for Austin blind salamander), between the outlets, and in dissolution cavities in the rocks underlying the outlets, Austin blind salamander is more likely to be in the subterranean parts of and between the outlets and in the dissolution cavities in the rocks underlying spring runs.

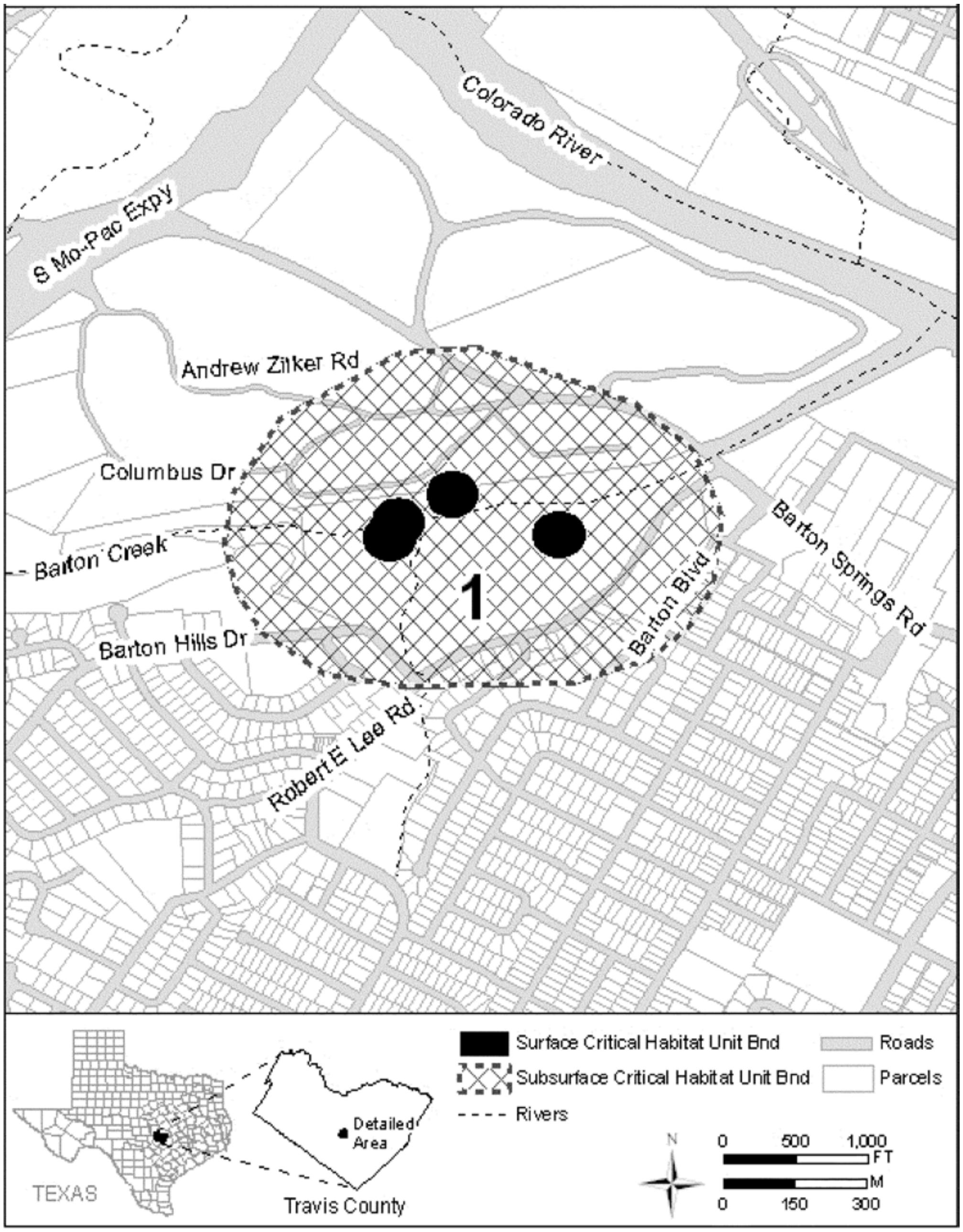


Figure 5-2: Service-designated Critical Habitat for the Austin blind salamander. Designated Critical Habitat has both surface and subsurface components. All of the surface habitat and most of the subsurface habitat, totaling about 120 acres, are within the City of Austin's Zilker Park and protected from future development. Source: Service, 2013a.

5.1.3 Reasons for Decline and Threats to Survival

The Service recently issued its final rulemaking on the Austin blind salamander (Federal Register, vol. 78, no. 161, p. 51278 and the following), which contains a comprehensive compendium of current information on, analysis of stresses on, and threats to this species (Service, 2013b). Such a comprehensive assessment was not made in the earlier listing process for Barton Springs salamander, but similar factors were identified and addressed in its Recovery Plan (Service, 2005).

In its listing rule, the Service has identified a relatively large number of specific stressors that adversely affect the Covered Species and that, either singly, in combination, or cumulatively over time, are reasons for decline and threats to survival of these species (Service, 2013b). These stressors are summarized in Table 5-1, which also provides an indication of the District's ability (legal authority; regulatory purview; financial wherewithal) to take actions that affect each of the stressors and thereby have a responsibility in responding to those threats. The District's Covered Activities do not relate to most of these threat stressors. They are included here primarily as an indication of the overall risks to the ecosystem of the Covered Species.

The primary threat for the Covered Species is believed to be the present and threatened degradation of the habitat by reduced water quality and quantity at the surface, in the subsurface, or both, and also by the physical disturbance of the surface habitat of spring sites (Service, 2013b). The Service has determined that in aggregate the threats identified are both imminent and high in impact on the Covered Species. For example, in its most recent listing rule documentation, the Service concludes that "…the Austin blind salamander is in danger of extinction now throughout all of its range…" and goes on to explain that this finding "…is based on our conclusions that this species has only one known population that occurs…in Barton Springs. The habitat of this population has experienced impacts from threats, and these threats are expected to increase in the future. We find that the [species] is at an elevated risk of extinction now, and no data indicate that the situation will improve without significant additional conservation intervention" (Service, 2013b). Although this specific determination addresses the Austin blind salamander, which was just recently listed, the same threats and stressors exist for the Barton Springs salamander population; and that species is considered equally at risk for exactly the same reasons and in need of conservation to reduce the risk of extinction.

But as Table 5-1 also indicates, most of the stressors and circumstances that harm the two species are beyond the District's ability and authority to affect, avoid, ameliorate, minimize, or mitigate. Only those reasons for decline and threats to the survival of the Covered Species that the District's activities affect in either a positive or negative sense are addressed further in this section of the HCP. The District HCP's Covered Activities relate solely to managed groundwater withdrawals from the Aquifer under its integrated drought management program. Managed withdrawals directly affect only the amount of groundwater that issues from the spring outlets. This is because water not withdrawn from wells discharges at spring outlets, generally on an equivalent-volume basis (Smith and Hunt, 2004). In turn, as described in Section 3.2.2.2, Ecological Setting, DO concentration in springflow decreases as springflow decreases (Herrington and Hiers, 2010) and TDS concentration in springflow increases as springflow decreases. TDS concentration increases because older, more saline water constitutes a larger proportion of low springflow than high springflow (Johns, 2006). These changes in water chemistry are affected indirectly by the District's groundwater management program, which in turn affects the amount of take of the Covered Species.

5.1.3.1 Barton Springs Salamander

The threats to and stressors of the Barton Springs salamander that are addressable by District actions and decisions and that potentially relate to the existence and amount of take and therefore its impact are the following (Service, 2013b):

1. Reduced springflow at the Barton Springs outlets during severe (Stage III Critical and Stage IV Exceptional) droughts, a type of stochastic (random, with a probability of occurrence/recurrence) event on which groundwater withdrawals are superimposed;
2. Decreased DO concentration in springflow during severe drought; and
3. Somewhat higher ionic constituent concentrations (as expressed by specific conductance) in springflow during severe drought.

The Service's Barton Springs Salamander Recovery Plan includes an examination of the various cultural/anthropogenic threats and stresses and recommends guidelines and action steps and an implementation program to minimize or avoid them as integral elements of the recovery measures (Service 2005). This District HCP is a complement to the Barton Springs Salamander Recovery Plan with respect to minimizing groundwater withdrawals during drought. Because natural processes such as supersaturation of dissolved gases in the salamander's body have occurred in the past and may pose continuing threats to the salamander (City of Austin, 2013; Service, 2005; 2013a), they may also bear on the feasibility and effectiveness of potential conservation measures for this HCP.

5.1.3.2 Austin Blind Salamander

The same factors identified and observations made for the Barton Springs salamander are also pertinent to the Austin blind salamander. This is especially true for those aspects of habitat change that can be affected by the District's Covered Activities; that is, the quantity and resultant water chemistry of springflow during severe drought that result in take and its impact:

1. Reduced springflow at the Barton Springs outlets during severe (Stage III Critical and Stage IV Exceptional) droughts, a type of stochastic (random, with a probability of occurrence/recurrence) event on which groundwater withdrawals are superimposed;
2. Decreased DO concentration in springflow during severe drought; and
3. Somewhat higher ionic constituent concentrations (as expressed by specific conductance) in springflow during severe drought.

Table 5-1: Summary of threats to Covered Species
Adapted from: Federal Register, vol. 78, no. 161, p. 51278 and the following.

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
Stressor A Present or threatened destruction, modification, or curtailment of its habitat or range	Water Quality Degradation	Urbanization	Increased impervious cover and chronic degradation of stream hydrology and contamination of aquatic habitat from expansion of roadways, residential, commercial and industrial development	No
			Increased magnitude and frequency of high flows and flashiness that disrupts biotic communities	No
			Changes in stream morphology and water chemistry, including increased contamination and toxicity	No
			Negative effects on prey base	No
			Increased sedimentation that covers graveled habitat	No
		Hazardous Materials Spills and Releases	Highway-transport accidents may release gasoline, chemicals, heavy metals like lead and arsenic, oil and grease, and toxic petroleum hydrocarbons to streams and then the Aquifer	No

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
			Releases of toxic organics and hydrocarbons from breaks in oil and gas pipelines and related facilities	No
Stressor A (continued)	Water Quality Degradation (continued)	Hazardous Materials Spills and Releases (continued)	Leaking underground storage tanks that release gasoline and petrochemicals to the Aquifer	No
			Breaks and overflows in conveyance lines and failures of treatment facilities for water and sewage that introduce a panoply of contaminants to streams and the Aquifer	No
		Construction Activities	Siltation and increased sediment and chemical loads from excavations for roads, tunnels, pipelines, and shafts	No
			Siltation and increased sediment and chemical loads from excavation and operation of quarries and gravel pits	No
			Disruption of hydrologic pathways from excavations (although none are known or likely for these species)	No
		Introduced Specific Contaminants and Pollutants	Acute and chronic toxicity to Covered Species and prey, through sediment or water	No
			Adverse effect on eggs and larvae	No
			Impaired reproduction, growth, and development of life cycle requirements	No

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
			Adverse effect on prey species availability	No
			Morphological deformities	No
			Altered capability for feeding, moving, and reproduction: loss of survivability	No
			Nutrient enrichment and subsequent changes in trophic state (indicator of amount of living material [usually algae] supported) and biological growth- and decomposition-related oxygen availability problems	No
Stressor A (continued)	Water Quality Degradation (continued)	Changes in Water Chemistry	Specific conductance may indicate other pollutants as well as elevated ionic stress	No
			Salinity and its specific ions can alter the internal water balance and create mortality in various species, including prey species	**Yes**
			Dissolved oxygen depression reduces respiratory efficiency, metabolic energy, and reproduction rates, and ultimately survival	**Yes**
	Water Quantity Degradation	Urbanization	Change in magnitude, frequency, and duration of runoff reduces base flow of recharge streams and concomitant decrease in aquatic community diversity	No

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
			Increased storm runoff increases erosion and sedimentation and more easily flushes larvae from materials on which it lives	No
			Reduction in infiltration increases flashy runoff, reduces recharge and therefore decreases springflow	No
		Natural Drought	Reduced springflow is associated with lower dissolved oxygen concentration, lower water velocities, higher salinity, higher temperature variations, and increased sedimentation of habitat, all of which adversely affect the Covered Species and availability of their prey	No
Stressor A (cont'd)	Water Quantity Degradation (continued)	Climate Change	Increased drought intensity and duration and higher average temperatures leads to more water demand, larger temperature variations, less recharge, smaller springflow, and more saline intrusion, all of which adversely affect the Covered Species and availability of their prey	No
		Increased Well Use	Reduced spring flow may cause stranding and interference with feeding/predation, as well as somewhat reduced dissolved oxygen and slightly higher salinity	**Yes**

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
	Physical Modification of Surface Habitat	Modification of Existing Habitat	Flooding may alter surface material and channel morphology, adversely affect protective vegetation, and flush individuals from their habitat	No
			Sedimentation mobilizes silt and clay that are suspended in water and make water turbid, which impairs breathing because of clogged gills and reduces ability to locate food or avoid predators	No
			Sedimentation mobilizes sediments and associated contaminants that are then re-deposited and cover/fill surfaces necessary for life activities.	No
Stressor A (continued)	Physical Modification of Surface Habitat (continued)	Modification of Existing Habitat (continued)	Impoundments alter stream morphology, and flow patterns that allow increased siltation and support larger predators.	No
			Other human activities, including frequent human visitation and vandalism, result in habitat disturbance/destruction and loss of cover available for breeding, feeding, and sheltering of Covered Species	No

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
Stressor B: Overuse for commercial, recreational, scientific, or educational purposes	Reduction in population size	Significant population declines	Over-collection for scientific purposes could negatively impact the species in combination with other threats; not considered a serious threat at this time	No
Stressor C: Disease or predation	Reduction in population size	Not considered a threat	No problems observed; not considered a threat to population	N/A
Stressor D: Inadequacy of existing regulatory mechanisms	Past, current, and future impacts to species as noted above	Inability to prevent further impacts to species in the future	Federal and State laws have not sufficiently prevented such impacts	No
			Local laws, regulations, and ordinances are not sufficient to prevent such impacts	No
			Groundwater Conservation District regulations are not sufficient to prevent such impacts	**Yes**

Threat Factor	Ecological Impact	Source of Concern	Adverse Effects	District Has Responsibility?
Stressor E: Other natural or man-made stressors affecting continued existence of the species	Synergistic and additive adverse interactions among stressors	Result of random events on very small population	Severe drought, abetted by groundwater withdrawals, may reduce quantity and change chemistry of springflow, which exacerbate other impacts on species, especially as re-colonization is not probable	**Yes**
			Catastrophic contaminant spills or leaks of harmful substances that exacerbate other impacts on species	No
		Other natural factors	Ultraviolet-B radiation may exacerbate other impacts	No
			The highly restricted range (one location) and the entirely aquatic environment make the Covered Species highly vulnerable to random events such as catastrophic spills, storms , and severe droughts that could eliminate the species	No

5.1.4 Survival Needs Affected by Covered Activities

Both the Barton Springs salamander and the Austin blind salamander are believed to have very similar needs to ensure their survival. At present, there are insufficient data and information to distinguish major differences between the species in this regard. Accordingly, the discussion in this section applies to both species.

Chief among their survival needs, as inferred from their sole habitat characteristics discussed in Section 5.1.1, Species Descriptions and Life Histories; and 5.1.2, Species Distribution, are the following:

1. A supply of high-quality freshwater with a relatively narrow range of physicochemical conditions of pH, alkalinity, and water temperature: These conditions are met by groundwater continuously discharging from a non-polluted karst aquifer (City of Austin, 2013; Service, 2013b);
2. Sufficient DO flux (volume per unit area per unit time), representing a combination of DO concentration and water velocity past the highly adapted salamander gill structures: The minimum flux required is unknown (Poteet and Woods, 2007; Mahler and Bourgeais, 2013);
3. Water with concentrations of ionic constituents (expressed as TDS concentration) that are sufficiently low such that the water supports the egg and larval life stages of the salamander (Service, 2013b): The threshold TDS concentration in springflow beneath which egg and larval life stages are supported is unknown, but it is believed to be high enough that minor increases in TDS concentration associated with saline water intrusion during severe drought do not affect egg and larval life stages;
4. Interconnected, submerged surface and subsurface habitat for various life activities and from time to time for protection: Given the morphological differences, the Austin blind salamander uses the submerged subsurface environment mostly, whereas the Barton Springs salamander uses the submerged surface and near-surface environment more. The interconnection between the submerged surface and near-surface environments may be critically important to both species for providing food and avoiding predation (Service, 2013b);
5. Given the small size of both populations and the lack of redundancy for each, the population's persistence (survivability) in the face of environmental and demographic challenges depends on the number, duration, frequency, and magnitude (size of reduction) of low springflow events at the spring outlets during severe droughts not exceeding the resiliency of the species (Service, 2013b).

These survival needs and life history requirements are characterized in more detail by the Service (2013b).

The District's Covered Activities and conservation program affect and address the first, second, and third of these needs, at least indirectly, and its drought management program is intended to reduce incrementally the magnitude of low springflow events that could affect the persistence of the population (the fifth need above). In the following section, the take by the Covered Activities is characterized and quantified, and then the impacts of take on the populations are described.

5.2 Effects of Take on Covered Species

The assessment presented in Sections 5.1.3, Reasons for Decline and Threats to Survival, and 5.1.4, Survival Needs Affected by Covered Activities, strongly suggests that the scientific basis and factors for considering take by the Covered Activities are essentially the same for both Austin blind salamander and Barton Springs salamander, differing primarily in amount of supporting information available. The COA's Barton Springs Pool HCP (City of Austin, 2013) does not distinguish differences in the effectiveness of protections afforded by its conservation measures between the two species. Further, substantially more information than is now known on the habitat requirements and life histories of both species, but especially Austin blind salamander, and their response to stressors would be needed to propose and assess differential requirements between the two species.

The unavoidable effects of the District's Covered Activities are also not able to be differentiated between effects on one of these species and not the other. Therefore, the effects on the species are addressed together in this section. However, potential differential impacts, that is, consequential results of take on each of the species populations, are addressed in Section 5.3, Impact of Take on Covered Species Populations. An important operational premise of this HCP is that the measures to be adopted for the conservation of Barton Springs salamander will not substantially harm Austin blind salamander and its habitat, and vice versa. The current state of knowledge appears to provide no compelling basis to refute this premise. In particular, there is no known difference in the sensitivity to DO concentrations and salinity between the two species, and while opportunistic predation may occur between the species, neither is known to be dominant in this regard (City of Austin, 2013).

Accordingly, in this section of the HCP addressing the effect of take, unless otherwise specified, the term "Covered Species" refers to both of the species and their attributes.

5.2.1 Experimental Assessment of Salamander Responses to Changes in Water Chemistry Related to Springflow

DO concentration and specific conductance have been identified as potentially significant parameters to be investigated during the course of the District HCP to understand the levels of stress on and mortality of both salamanders (for example, Turner, 2004b). Before the HCP was begun, no scientific study of the physiological responses of either Covered Species to changes in these parameters was known. Accordingly, a pioneering multistage laboratory study was commissioned and funded by the District as part of the HCP. The research was done by investigators at The University of Texas at Austin, Section of Integrative Biology, and later supplemented by researchers at Baylor University's Department of Environmental Science. In the first stage of the work, the investigators evaluated stressor-response relationships and sensitivities important to conservation on Barton Springs salamander and a surrogate species across a range of DO concentrations and specific conductances (Poteet and Woods, 2007).

Approaches that identify stressor-response thresholds (DO concentrations below which, and specific conductances above which, likely harm salamanders) are valuable for supporting environmental management decisions (Suter, 2006). The work with specific conductance showed no appreciable response by a surrogate (for the Covered Species) salamander to specific conductances several multiples higher than those in Barton Springs flow. Those findings are discussed below at the beginning of Section 5.2.1.2, Stressor-Response Study Findings and Applications. On that basis, the investigators, with the District's concurrence, discontinued further analysis of response to specific conductance variations and focused exclusively on analysis of response to DO concentration variations. Thus, the stressor-response experiments for the District HCP were designed to determine hazards to individuals from just one of the stressors of the Covered Species, DO. Although Covered Species are susceptible to cumulative risks from a variety of natural and anthropogenic stressors (Table 5-1), stress from incidental DO concentration variability is considered the primary stressor to which the District's Covered Activities contribute. This approach (focusing on the primary stressor) is preferred when considering threatened and endangered species for which an adverse impact on individuals of the population can be significant (Suter, 2006).

The first-stage study documented in the report by Poteet and Woods (2007) was subsequently enhanced with further investigation, computations, and analysis as part of the HCP, using a Probabilistic Ecological Hazard Assessment (PEHA) approach to relate the laboratory study findings to threshold responses of salamanders to DO concentrations in spring habitats for the first time. This second-stage study, which involved a closely related salamander species as a surrogate for the Covered Species and historical data, provided a unique contribution to understanding DO stress to an endangered species. The enhanced study report was subjected to considerable peer review before being published in *Copeia*, the journal of the American Society of Ichthyologists and Herpetologists (Woods et al., 2010). The report is included in its entirety as Appendix I. The HCP relies heavily on the conclusions in the published report, but data in the original report (Poteet and Woods, 2007) are also instructive.

5.2.1.1 Laboratory Study Design

The investigators selected and used a closely related salamander species, the San Marcos salamander (*Eurycea nana*), as a surrogate for the Covered Species because its genetics and life history are similar to those of the Barton Springs salamander (Chippindale et al., 2000). San Marcos salamander occupies similar karst-fed springs in Central Texas, and the two species have similar physiologies. Both species are federally protected, but the captive population size of San Marcos salamander is considerably larger than that of Barton Springs salamander and especially Austin blind salamander (Poteet and Woods, 2007). On the basis of metabolic tests on both species to evaluate response to changes in DO concentration and specific conductance (Poteet and Woods, 2007), San Marcos salamander appeared to respond similarly to the Barton Springs salamander under a variety of test conditions. The ready, nearby availability of a surrogate species that was so similar to the Covered Species was fortuitous and exceptionally rare for stressor-response studies with endangered amphibians (Woods et al., 2010).

Woods et al. (2010) used the testing procedure of Poteet and Woods (2007) (Figure 5-3) to generate mortality estimates after 28 days of exposure to various DO treatment levels under controlled laboratory conditions. In addition, Woods et al. did a 60-day study on juvenile San

Marcos salamander, exposing individuals to various DO concentrations to provide data on sub-lethal effects such as metabolic rate variation, growth rate, and behavioral response. Survival and sub-lethal growth measurements are routinely used in ecological hazard assessments because these response variables are highly relevant for population sustainability of threatened and endangered species (Suter, 2006).

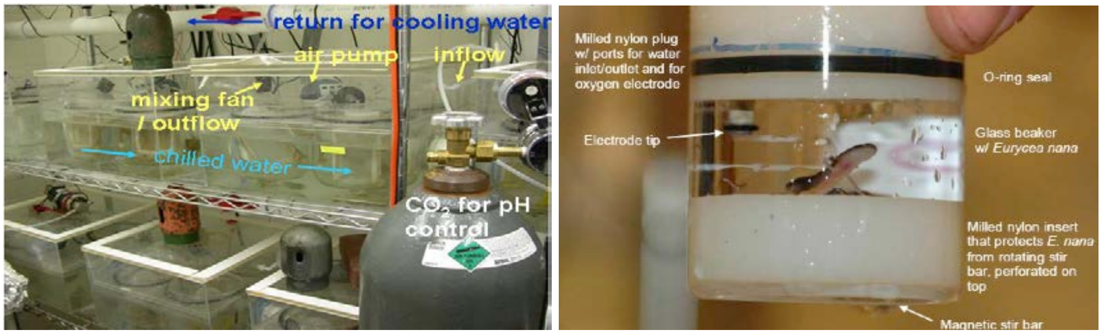


Figure 5-3: Example setups for studying salamander response to stressors .
Representation of two laboratory experimental setups to measure salamander response to stressors in the study of Poteet and Woods (2007). Image on left is for 28-day stressor-response study; and image on right is for metabolic rate study. (Photo courtesy of M. Poteet and A. Woods).

5.2.1.2 Stressor-Response Study Findings and Applications

One of the primary findings of Woods et al. (2010), in further assessing the results of Poteet and Woods (2007), was that increases in specific conductance do not result in salamander mortality, even increases to very high specific conductances. This finding is the result of what appears to be the only laboratory study available for the species of concern. The finding is not surprising, particularly for organisms that have adapted to natural habitat changes in the past. However, the finding relates only to adult and juvenile salamanders. Others have suggested that increased salinity could have adverse consequences on the egg and larval stages of the salamander (Service, 2013b). No empirical studies of this latter possibility have been documented. But given the relatively small increase in TDS concentrations (from about 400 mg/L to less than 500 mg/L) associated with low springflow (Herrington and Hiers, 2010) and the adaptation of Covered Species populations to low springflow, any adverse effect on the Covered Species is likely negligible. The Covered Species are exposed to similar and even larger salinity variations on a recurring basis during high-flow periods, although the durations of such periods are over much shorter time intervals than those of severe drought. Accordingly, salinity was not considered by the investigators to be nearly as important a factor as DO concentration in affecting habitat quality for purposes of biological evaluation in the District HCP. The narrative that follows thus focuses only on DO. Although many natural and anthropogenic chemical constituents that may occur in groundwater could adversely affect the Covered Species, the District's Covered Activities only affect the concentration of those few natural constituents that are specifically related to springflow. In this regard, only DO concentration is judged to be a quantitative indicator of take of the Covered Species in the meaning of the Act.

In the 28-day adult stressor-response study, groups of salamanders were exposed to progressively larger DO concentrations: 1.3, 2.4, 3.6, 4.6, and 7.5 mg/L, each in individual aquariums. Figure 5-4 shows a response curve to the DO exposure concentrations. Mortality fell abruptly between about 2 and 4 mg/L. Some salamander mortality occurred within 28-days in each of the three lowest treatments (1.3, 2.4, and 3.6 mg/L), and there was 100% mortality within 48 hours in the two lowest treatments; no DO-related mortality was observed in either of the two highest treatments (4.6 and 7.5 mg/L).

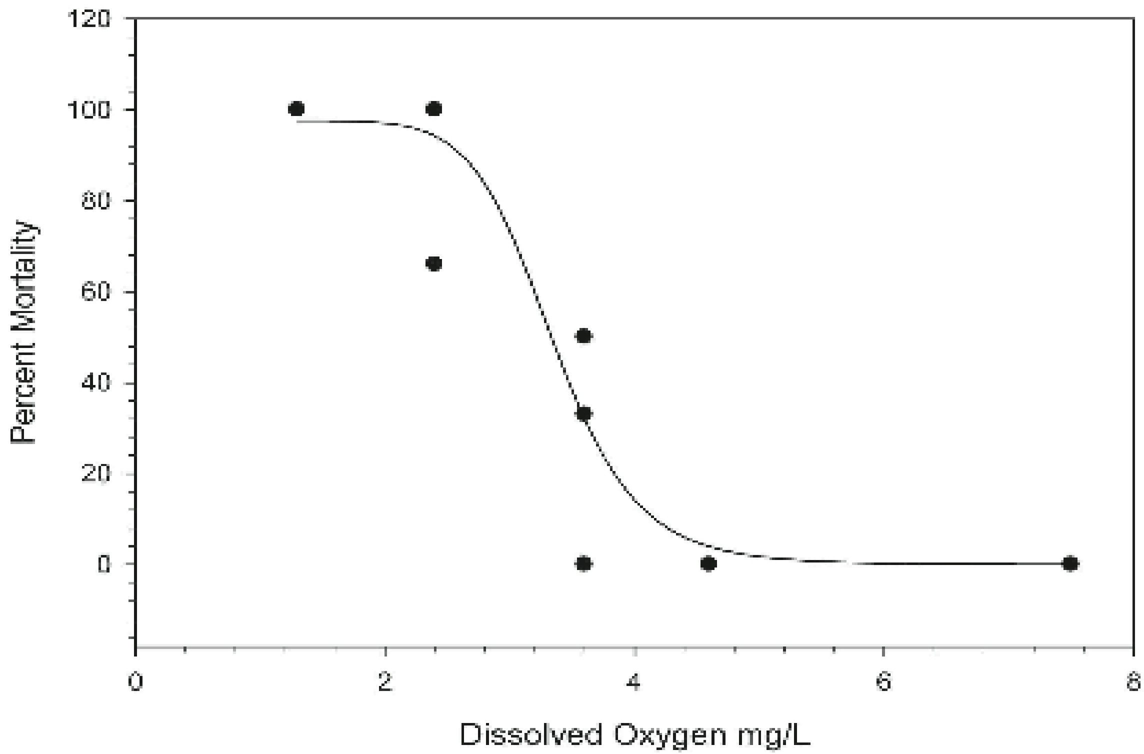


Figure 5-4: Relationship between mortality of San Marcos salamander and five exposure concentrations of dissolved oxygen in a laboratory study.
Source: Woods et al. (2010).

Lethal Concentrations (LC_x) are estimated concentrations of an environmental parameter at which level a certain animal or organism has a given likelihood (percent chance) of dying in a given amount of time, under constant, controlled conditions. In other words, LC_x is the exposure concentration (level) in which x% of the organisms die. Woods et al. estimated a series of LC_x values of DO for the Barton Springs salamander—the DO concentrations that would presumably cause 5%, 10%, 25% and 50% mortality for adult San Marcos salamander individuals if exposed continuously over a 28-day period (Table 5-2; Woods et al., 2010):

Table 5-2: Summary Lethal Concentrations and Dissolved Oxygen Concentration (Woods et al., 2010).

The +/- values represent the 95% confidence interval (see next Section 5.2.1.3, Implications and Limitations of the Stressor-Response Study).

Lethal Concentrations (LCx)	Dissolved Oxygen Concentration (mg/L)
LC_5	4.5 ±0.5
LC_{10}	4.2 ±0.3
LC_{25}	3.7 ±0.1
LC_{50}	3.4 ±0.2

These concentrations represent DO stressor-response thresholds for San Marcos salamander, a reasonable surrogate species for the Barton Springs salamander and, for this HCP, also Austin blind salamander. In particular, the LC_{50} and the LC_5 may provide useful benchmarks for estimating the quantity of take and negligible ecological risk that is likely to occur under the anticipated springflow conditions of the HCP. For example, the concentration of DO at LC_{50} (causing 50% chance of mortality after 28 days of exposure) is about 3.4 mg/L, which, if it occurred for a continuous 28-day period or longer in one of the springs, would pose a grave threat to salamander survival. On the other hand, DO levels at or above LC_5, 4.5 mg/L, showed no observable effects in any experiment (Woods et al., 2010), so little threat to salamander survival would be inferred. During prolonged, severe droughts, the DO concentrations typically range non-linearly between these two DO levels (Woods et al., 2010).

In this regard, other researchers have also noted that the Barton Springs salamander seems to be adapted to waters that are variably undersaturated with respect to DO (Turner, 2007), which indicates some resiliency of the salamander to DO variations.

The stressor-response study also yielded the No Observed Adverse Effect Level (NOAEL) threshold DO levels for juvenile as well as adult San Marcos salamander. Juvenile growth rate studies were done over a 60-day period to determine the effects of exposure to various DO levels on metabolic activity and growth. The lowest DO concentration for the 60-day juvenile growth study was 4.4 mg/L.

The results of the 60-day analysis are shown in Table 5-3. Although juveniles in the lowest DO exposure concentration (4.4 mg/L) had growth rates that were approximately 30% lower than control salamanders, the growth rates were positive and were not significantly different than those of the controls (Woods et al., 2010). Uncertainties exist, but based on these unique laboratory studies, salamanders exposed to DO concentrations at or higher than 4.4

mg/L are not expected to be adversely affected.[13] For purposes of this HCP, the NOAEL for all forms of the Covered Species is considered 4.5 mg/L DO.

Table 5-3: Summary of growth rates of juvenile San Marcos salamander over 60 days in different dissolved oxygen concentrations.
Source: Woods et al. (2010).

Treatment	Dissolved Oxygen (mg/L)	Number	Growth Rate (mg/day)
1	4.44	5	0.15
2	5.17	4	0.33
3	5.31	4	0.26
4	6.35	5	0.24
5	8.22	4	0.23

The PEHA used by Woods et al. is based on USGS datasets of DO concentration and springflow representing 30 years of record. The procedures used were uniform across the datasets, which was a major criterion for the PEHA investigation. In those datasets were very few observations of DO concentration at low flows or values below 4.5 mg/L. The DO dataset for the primary outlet at Main Springs contained more of these observations than datasets for other outlets; but there were only 27 observed springflow-DO concentration pairs in which springflow was less than 20 cfs in that dataset, and only 35 DO concentration observations less than 4.5 mg/L. The mean of the 27 DO concentrations paired with springflows less than 20 cfs is 4.69 mg/L. No statistically significant relationship was observed between flows below 20 cfs and associated DO levels. This result imposes some limitation on the general applicability of the findings and their comparability with findings from datasets collected later for other outlets.

The PEHA was used to estimate the likelihood (percent chance) that DO concentrations in springflow at Main Springs, Eliza Spring, and Old Mill Spring would be at or below response thresholds for San Marcos salamander. A likelihood estimate can also be called a nonexceedance probability and can refer to the percentage of time a concentration is at or below a response threshold.

[13] Some reviewers of early drafts of this HCP noted that a higher standard, specifically the 5.0 mg/L DO criteria for lentic (still water) systems should be used, in keeping with existing surface water quality standards and/or for providing a safety margin. This is not a comparable standard and is used for different purposes. The surface water quality standard is intended to provide a general condition that would support a diversity of aquatic life under all ambient conditions in lakes and reservoirs with other constituents and is applied only outside a mixing zone. In any event, it is not applicable to springflow per se or spring-fed pools. Further, it is not intended to be equivalent to a NOAEL for any specific aquatic species, nor is it designed to be used as a threshold for assessing take. Sound environmental management incorporates margins of safety in actual enforceable standards whenever feasible to accommodate cumulative effects of all constituents. But standards that have such safety margins do not indicate when physiological and/or behavioral effects for a given species are evident, including in particular these Covered Species. Woods et al. (2010) assert that the typical 5.0 mg/L DO surface water quality criteria, if it were applicable, would likely be protective of the Barton Springs salamander; but those researchers did not indicate that such a lake or reservoir standard is applicable for spring feed pool habitats nor even the minimum water quality criterion for the salamander, below which DO impacts are evident.

Table 5-4: Likelihood (percent chance) that DO concentrations in springflow at Main Springs, Eliza Spring, and Old Mill Spring would be at or below response thresholds for San Marcos salamander.

Response thresholds (LC_x) are DO concentrations that cause mortality in 5, 10, 25, and 50% of adult San Marcos salamander after 28 days of exposure, and the No Observed Adverse Effect Level (NOAEL) for juvenile San Marcos salamander growth following a 60-day study. The +/- values represent the 95% confidence interval (see next Section 5.2.1.3, Implications and Limitations of the Stressor-Response Study). Source: Woods et al. (2010).

Response Threshold (LC_x)	Length of Study	Response Threshold DO Conc. (mg/L)	Probability of Nonexceedance (Percent chance DO conc. at or below response threshold conc.)		
			Main Springs	Eliza Spring	Old Mill Spring
LC_5	28-day	4.5 +/- 0.5	5.2	6.8	30
LC_{10}	28-day	4.2 +/- 0.3	2.3	3.024	--
LC_{25}	28-day	3.7 +/- 0.1	0.4	0.4	15
LC_{50}	28-day	3.4 +/- 0.2	0.08	0.1	11
NOAEL	60-day	4.4	4.5	5.8	28

Table 5-4 data indicate, for example, that the probability that the DO concentration in flow at Main Springs would be less than the concentration at or below which 5 percent of the salamanders would be expected to die after 28 days of exposure (about 4.5 mg/L) is 5.2%. Or briefly, the probability of a DO concentration at Main Springs not exceeding about 4.5 mg/L is 5.2%. Similarly, for Eliza Spring, the nonexceedance probability for the same response threshold is 6.8%; and for Old Mill Spring, 30%. At the other end of the mortality spectrum, Table 5-3 data indicate that the LC_{50} concentration (about 3.4 mg/L), the level at which 50% mortality of salamanders would be expected after 28 days of exposure, has a likelihood of occurring 0.1% of the time, or less, for Main Springs and Eliza Spring. The probability of nonexceedance of the NOAEL for Main Springs is 4.5%, and for Eliza Spring, 5.8%. Thus, there is a 4.5 % likelihood of a DO concentration not expected to adversely affect juvenile salamander growth (4.4 mg/L) at Main Springs. Nonexceedance probabilities for Old Mill Spring were substantially higher than those for the other two springs.

Results from the PEHA were also expressed in the form of toxicological benchmark concentrations for low percentiles (Table 5-5). For example, the data in the table indicate that 5% or less of DO concentrations measured in flow at Main Springs in a representative typical period would be expected to be at or below a concentration of 4.5 mg/L.

Table 5-5: Toxicological benchmark concentrations for low percentiles, Main Springs, Eliza Spring, and Old Mill Spring.
Benchmarks based on the DO concentration distributions for the three spring outlets. Likelihood estimates are based on the 28-day adult mortality and 60-day juvenile growth studies. Source: Woods et al. (2010).

	Dissolved Oxygen Concentration (mg/L)		
Percentile	Main Springs	Eliza Spring	Old Mill Spring
1st	4.0	3.9	2.3
5th	4.5	4.4	2.9

The USGS datasets used by Woods et al. reflect an indeterminate and variable mixture of different regulatory conservation measures over a time period. Moreover, a more representative dataset that contains additional data, including low-flow data, has been collected by the COA, and both the COA dataset and the USGS dataset are now accessible and further analyzed (Turner, 2007; Turner, 2009). Accordingly, a different paired DO concentration-springflow dataset, in conjunction with the lethal concentration(LC_x) statistics of Woods et al. (2010), is used to associate DO concentration and springflow in estimating the frequency and amount of take for this HCP. However, as would be expected, the datasets are similar and the general relationships that resulted from the Woods et al. PEHA are considered valid.

5.2.1.3 Implications and Limitations of Stressor-Response Study

The PEHA and other methods applied in this research are helpful in characterizing some of the parameters of potential take of the Barton Springs salamander, and by extension, the Covered Species in the field. There are, however, additional areas of uncertainty. As in all laboratory studies, the response of the test organisms under controlled conditions may not be the same as their response to DO concentration variations in the field. Response also varies among individuals, affecting the precision of mortality estimates. This potential variability is accounted for by showing a 95-percent confidence interval around the mean[14] of each LC_x in Table 5-3 and text in previous Section, 5.2.1.2, Stressor-Response Study Findings and Applications. The surrogate species San Marcos salamander appeared to react similarly to Barton Springs salamander among laboratory treatments when metabolism was monitored, but San Marcos salamander mortality estimates may or may not align as well with those expected in the Covered Species populations in the field, particularly in any given time period (Woods et al., 2010). Mortality estimates are only for adult salamanders, so other life stages may have different or more variable sensitivities to reduced DO concentration (or increased ionic constituent concentrations) in groundwater.

Further gaps in knowledge that would have been useful to examine but were beyond the scope of the project include how DO concentration (and specific conductance) affects reproduction, egg

[14] A confidence interval about a mean is an estimate of the uncertainty that that mean, which is the mean of a sample, represents the true mean of the population. In other words, if 100 of samples of the same size were collected and a 95% confidence interval computed about the mean of each sample, we could say that 95 of the 100 computed intervals would likely contain the true mean of the population.

development, and hatching (Wood et al., 2010). If other stages—eggs or juveniles—are more sensitive (show higher LC_{50}), higher DO concentration than that determined for the adult NOAEL may still constitute a considerable threat. For example, no data are available to evaluate mortality responses of Barton Springs salamander eggs to DO concentration.

Salamanders will occupy habitat characterized by high and low DO concentration (or other factors, such as water flow velocities that affect DO availability). Although sensing and responding to such varying DO conditions may be irrelevant at high DO concentrations, it likely becomes more important at low DO concentrations. In the salamander stressor-response experimental program, salamanders clearly perceived and responded to low (or decreasing) DO concentration—the infrared detection system measured the onset of activity during decreasing DO concentration and cessation of activity during subsequent increasing DO concentration. In the field, counts of salamanders tend to decline in Barton Springs when DO concentration decreases below approximately 5 mg/L (Turner, 2004b). Salamanders in local pockets of low-DO water may migrate and find higher-DO water, either in the submerged surface environment outside the outlets (Turner, 2007) or inside the subterranean karst system (Service, 2013b; Hillis et al., 2001). Water flow velocities in the salamander experiments were, for technical reasons, fairly low (1 cm/sec), likely resulting in substantial boundary layers (water nearest the bottom of the flow) with still lower flow velocity and DO concentration. Consequently, another possible response mechanism to low DO concentration would be for salamanders to increase oxygen exchange across the gills by disrupting those boundary layers—for example, by bobbing, flicking their heads, or swimming. The novel stressor-response thresholds observed by Woods et al. (2010) appear to be satisfactory. But they may be effective only for shorter periods of time than a typical groundwater drought, during which the metabolic energy required eventually exceeds the energy gained by incremental benefits to respiration.

Inherent variability in DO concentration and specific conductance exists in the springs inhabited by the Covered Species, possibly due to poor mixing of waters from different flow routes discharging along the faults as well as differences in re-aeration potential between confined and unconfined parts of the Aquifer adjacent to the spring orifices. Microhabitats may be higher or lower in DO concentration than data measured by the COA. In addition, test organisms during the laboratory study were not able to move to higher-quality habitat conditions (that is, areas with higher flow velocities to increase oxygen exchange across the gills), as they can in the field. On the other hand, sub-lethal effects observed in the laboratory (such as reduced activity) may not have contributed directly to mortality estimates in the tests, but in the field such behavioral changes may increase predation risk, reduce foraging, or have other effects that increase take and even the chances of mortality. Finally, reduced DO concentration may significantly contribute to cumulative adverse effects with other changes in other springflow-related and non-springflow-related water chemistry parameters during low flow, which could not be accounted for in these tests.

Despite the uncertainties that affect the use of laboratory-derived mortality estimates to describe the mortality risk to the population in the field, the data collected and analyzed by Woods et al. (2010) provide the best basis to describe the anticipated impact to the Covered Species of low-flow conditions at the Barton Springs complex. These study results can be used in conjunction with continuous water quantity and corresponding water chemistry data and salamander survey data collected by the COA, USGS, and the District to describe parameters of incidental take of the Covered Species under the District HCP. With estimated responses to changes in DO concentration (Woods et al., 2010) and known relationships between DO and springflow (Porras, 2014; Turner, 2007) and salamander survey data during a range of aquifer conditions, it is possible to estimate the response of the Covered Species to reduced DO concentrations associated with low flows. The estimated responses form a rational and the best-available basis for determining adverse effects, and ultimately take.

5.2.2 Spatial and Temporal Extent of Take

Take, as defined by Federal Register section 50 CFR 17.3, includes both harm and harassment of the Covered Species. Harm is defined as "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." Harassment is defined as "annoying wildlife so as to significantly impair [those] behavioral patterns."

Estimates of take of the Covered Species at the perennial spring outlets are based primarily on two measurable life requirements of the species: (1) rate of springflow, and (2) its associated changes in DO concentrations.[15] Both the Covered Activities and natural variability and can cause similar reductions in springflow and DO concentration. However, the Covered Activities can hasten and reduce springflow and DO concentration beyond the natural variability. The Covered Activities' influence on springflow and DO concentration that causes harm and harassment to the Covered Species is the basis for the District's Incidental Take Permit (ITP).

Using the studies of Woods et al. (2010) described in Section 5.2.1, Experimental Assessment of Salamander Responses to Changes in Water Chemistry Related to Springflow, the District has identified two general responses from the species that may constitute incidents of take from the Covered Activities under certain circumstances. The first is an initial behavioral response when springflow is equal to or less than 30 cfs and the corresponding DO concentration is equal to or less than 5.0 mg/L. The second is a physiological response when springflow is equal to or less than 20 cfs and the corresponding DO concentration is equal to or less than 4.5 mg/L.

However, while the Covered Activities will be continuously occurring, they do not always result in take. During non-drought conditions, the incrementally smaller springflows at the perennial outlets that are partly a result of the Covered Activities are not accompanied by changes in water chemistry that have behavioral or physiological relevance to the Covered Species. As noted above, the springflow threshold where take begins is 30 cfs.

For purposes of this HCP, the District is making an assumption related to adverse effects of decreases in DO concentration on the Covered Species other than those experimentally evaluated: In the absence of quantitative flow-specific data, any other potential adverse sub-

[15] Water temperature also may be important in defining the short-term temporal DO conditions, owing to the reduction in DO solubility with higher temperatures. But temperature effects are reflected primarily in the variability of DO concentrations observed for a particular springflow. Under base-flow conditions, temperature of water discharging at the outlets tends to be cooler and more uniform and less likely to control DO concentrations than the proportion of saline and other older, less meteoric groundwater in springflow (Mahler and Bourgeais, 2013).

lethal effects are assumed to also begin at the same time as the take indicated by the laboratory-determined physiological responses. Such other sub-lethal effects may be expressed at either the individual organism level or at the population level. At the organism level, potential effects include other physiological responses such as impaired egg production and development, reduction in reproductive success, reduction in recruitment, and/or detrimental behavior. At the population level, they include reduction and cessation of reproduction, reduction and cessation of growth, reduction in prey abundance, and increased intra-and inter-specific competition.

While the Covered Activities take place over the entire ITP Area, the resultant take will occur at or near the spring outlets. Take affects the populations at each outlet to somewhat different degrees and at slightly different times, depending on the total spring discharge and resultant water levels and chemistry. Table 5-6 shows the baseline flows and recurrence (nonexceedance) frequencies (percentage of time flow is at or below a designated rate) for each outlet that correspond to take resulting from habitat, behavioral, and physiological responses. Combined flows greater than 30 cfs (DO concentration > 5.0 mg/L) are not considered to annoy, harass, or harm the Covered Species at any perennial outlet as a result of the Covered Activities; therefore no take occurs. Combined flows greater-than-20 through 30 cfs (4.5 mg/L < DO concentration ≤ 5.0 mg/L) cause mostly sub-lethal behavioral effects and therefore, annoy or harass (take) the Covered Species as a result of the Covered Activities. Combined flows equal to or less than 20 cfs (DO concentration ≤ 4.5 mg/L) cause physiological sub-lethal to lethal effects and therefore, annoy, harass, or harm (take) a variable portion of the Covered Species as a result of the Covered Activities.

Table 5-6: Onset of take by spring outlet.
Flows and frequencies in the table pertain to the HCP pumping scenario, with current (2014) levels of authorized groundwater withdrawals and after implementation of the set of HCP conservation measures (described in Section 6.2, Minimization and Mitigation Measures) but without DO mitigation measures and benefits of the City's HCP activities. Additional explanation is in Appendix J.

Outlet	Habitat Loss (cfs)	Recurrence Frequency	Behavioral Change (cfs) when DO ≤5.0 mg/L	Recurrence Frequency	Physiological Change (cfs) when DO ≤4.5 mg/L	Recurrence Frequency
Main	n/a	n/a	27	32%	19	19%
Eliza	n/a	n/a	29	35%	20	20%
Old Mill	n/a	n/a	29	35%	18	16%
Upper BS	40	48%	n/a	n/a	n/a	n/a

As drought becomes prolonged and deepens, the effects on *individual* organisms are likely to proceed from an initial sub-lethal, annoyance/harassment form of take for a few individuals to a progressively more harmful form of take that affects increasingly larger numbers of individuals and that ultimately includes mortality. The rationale and methodology used to develop thresholds for these effects are discussed in Section 5.2.1.1, Laboratory Study Design. They are summarized in this section to provide support for this discussion of the spatial and temporal context for take.

Adverse effects also occur due to the incremental physical habitat loss caused by reduced springflow during recurring drought cycles. This is most noticeable in the temporary reductions and losses of spring habitat at Upper Barton Spring, a non-perennial overflow spring with a small population of Barton Springs salamanders. As noted earlier, Upper Barton Spring stops flowing when combined flow in the Barton Springs complex is less than 40 cfs. This is a recurring condition related to the elevation of the Upper Barton Spring outlet relative to water levels in the Aquifer. That is, flow ceases when the water level at the outlet falls below the elevation of the outlet. This condition would occur about 38% of the time without the Covered Activities, and it will occur about 48% of the time with the Covered Activities and the HCP conservation measures in place.

At Upper Barton Spring there is likely no adverse physiological response associated with the water chemistry at springflows around 40 cfs. This lack of response is supported by the re-appearance of relatively robust individual Barton Springs salamanders at this outlet when the Aquifer water level at the outlet rises above the outlet and Upper Barton Spring begins flowing again (City of Austin, 2013). But it is reasonable to assume that the physical loss of most of the surface habitat at Upper Barton Spring affects the entire salamander population at this outlet by causing a retreat of salamanders into the subterranean habitat; and perhaps including migration of some fraction of the resident population to other outlets. Although no life functions are known to be permanently impaired for these species by this inherent and frequently recurring loss of physical habitat, the population is reasonably inferred to be annoyed, and some adverse effects on feeding and sheltering behavior are likely. Because withdrawals contribute to the decline of water levels in the Aquifer (even though only a very small fraction at springflows around 40 cfs when physical habitat loss starts to occur), some portion of the adverse effects on the Upper Barton Spring population, primarily a sub-lethal form from annoyance and harassment, is attributable to the Covered Activities and is therefore take.

5.2.3 Consideration of Take and Jeopardy

The populations at or near each outlet at a given time are potentially adversely affected by changes in flow and water chemistry at the respective outlet. As described in Section 5.2.2, Spatial and Temporal Extent of Take, at least a fraction of that adverse effect is created by decreased springflow derived from withdrawals by nonexempt permitted wells, the Covered Activity. Therefore take occurs, and the amount of take depends on the size of the population that exists at a given time and the proportion of adverse effects that are associated with natural variations in springflow that would occur regardless of the Covered Activities. When non-drought conditions are re-established, the adversely changed characteristics of springflow may no longer exist, but the take incident associated with the just-ended drought has already occurred and does not decrease. So incidents of take are estimated on the basis of a correlation between springflow and DO concentration and are cumulative over multiple District-declared droughts that will occur during the ITP term.

5.2.3.1 Estimation of Sizes of Populations Adversely Affected

The District uses different approaches to estimate the sizes of the populations that control take of the two Covered Species.

<u>Barton Springs Salamander</u>

The COA has regularly conducted census surveys of the Barton Springs salamander and since 2003 has used essentially the same protocols and standards for its surveys. The statistics on abundance, density, and their variation from these censuses (City of Austin, 2013) provides an internally consistent, extensive dataset from which to gauge the size of the surface population for this species at the time of each census. The District's estimate of total take for the Barton Springs salamander is based on these data.

The COA noted in its Barton Springs Pool HCP that salamander abundance based on census counts varies with environmental conditions (City of Austin, 2013). Accordingly, the District considers the actual salamander population present in a perennial outlet during periods when DO concentration is below the salamander take threshold to be the adversely affected population. To reduce this adversely affected population to a single numerical estimate as required for the ITP, the District has designated the number of individuals experiencing incidents of adverse effects arising from DO-related behavioral or physiological effects at the spring outlets to be equivalent to the arithmetic mean-plus-one standard deviation (SD) of the abundance data from the COA's aggregated census counts for each outlet. This metric represents the population that experiences adverse behavioral or physiological effects from low DO concentrations related to springflow. This metric incorporates and reflects a measure of variability from environmental conditions as well as a central tendency. The approach also provides some accommodation for other factors affecting take and the uncertainty of future environmental conditions than would be reflected in current salamander counts. The COA also uses a "mean-plus-one SD" approach, indexed to salamander densities observed in specific subareas, to facilitate evaluation of take in the COA's subarea-specific covered activities (City of Austin, 2013).

As described in Section 3.2.2.2.1, Overview of Habitat Characteristics and Supported Populations, this HCP has designated the "stipulated population" of Barton Springs salamander that encounters adverse effects and its distribution among the perennial outlets to be as shown in Table 5-7.

Table 5-7: Total stipulated population of Barton Springs salamander by perennial spring outlet. The estimate for non-perennial Upper Barton Spring is 18 individuals.

Perennial Outlet	Stipulated Population
Main Springs	160
Eliza Spring	624
Old Mill Spring	37
Total Stipulated Population	821

This HCP does not quantitatively differentiate sub-lethal effects from changes in DO concentration on reproduction, natality (birth rate), recruitment (rate at which juveniles mature to reproduction age), reducing other growth, reducing prey/food abundance, and increasing intra- and inter-specific competition(Gillispie, 2011). Similarly, it does not quantitatively differentiate the potential adverse effects from either physiological response or behavioral effects from changes in DO concentration. To the District's knowledge, quantitative relationships between and among these factors for the Covered Species do not exist. Individually, they are assumed to be small relative to the behavioral or physiological effects associated with DO reductions in springflow, but in aggregate and cumulatively, they may produce appreciable adverse effects. Further, for simplicity, that portion of the Barton Springs salamander population with habitat that is inaccessible from the surface and therefore not accounted for directly in the COA's censuses but that may be adversely affected is considered to be included in the stipulated population at the perennial outlets. In absence of relevant data, the District assumes that the use of the mean-plus-one-SD metric includes all portions of the population that are being adversely affected, whether by lethal or sub-lethal effects.

For non-perennial Upper Barton Spring, because the entire surface habitat is lost when the combined Barton Springs flow decreases below 40 cfs, its entire stipulated population is adversely affected. The mean-plus-one-SD metric representing that population is 18.

Austin Blind Salamander

The surface-habitat censuses of the Austin blind salamander conducted by the COA (and that are useful for its covered activities) are not considered to accurately reflect the entire population of that subterranean species. For this reason, the mean-plus-one-SD approach used for the Barton Springs salamander is not appropriate for estimating the population of this species that is adversely affected. As explained in Section 3.2.2.2.1, Overview of Habitat Characteristics and Supported Populations, the District has made an evaluation of the size of this cryptic population by using a set of inferences and assumptions that yields an approximation of the population size for purposes of this HCP. Accordingly, the District has designated the stipulated population of Austin blind salamander that encounters adverse effects and its distribution among the perennial outlets to be as shown in Table 5-8.

Table 5-8: Total stipulated population of Austin blind salamander by perennial spring outlet..

Perennial Outlet	Stipulated Population
Main Springs	877
Eliza Spring	111
Old Mill Spring	12
Total Stipulated Population	**1,000**

5.2.3.2 Apportionment of Take to Adversely Affected Populations

To quantify incidents of take, the District has developed a monthly "take factor" that accounts for both lethal and sub-lethal forms of take of each species by the Covered Activities when springflow is below 30 cfs. To arrive at these factors, the District has integrated laboratory results (Poteet and Woods, 2007; Woods et al., 2010), long-term field observations, regulatory program requirements, hydrogeologic modeling (Smith and Hunt, 2004), and statistical modeling to estimate the adverse effects and percentages of the stipulated populations that experience incidents of take. The District constructed a step-wise (spreadsheet) model of springflow, withdrawals, management scenarios, and DO correlations on a monthly basis over the 97-year period of record (Appendix J). The model provides detailed information on the hydrologic relationships, statistics, and rationale used to inform the HCP. The following are definitions of terms used in the modeling scenarios discussed in this section (Section 5) and Appendix J:

a. Groundwater Management Scenarios

1. Exempt-only Pumping – a baseline scenario that results in springflow without effects of the Covered Activities (that is, without effects of nonexempt permitted pumping).

2. Pre-HCP Pumping – a scenario that represents conditions that existed in 2004, just before the HCP program and preemptive conservation measures were initiated.

3. HCP Pumping – a scenario that represents conditions after implementation of the proposed conservation program for the Covered Activities, with all proposed HCP measures to avoid, minimize, and mitigate take of the Covered Species.

b. Reference Droughts

1. Drought of Record (DOR) – the severe drought of the first 7 years of the 1950s.

2. Recent Severe Droughts (RSD) – a series of three severe droughts from mid-2005 to mid-2012, which includes the groundwater drought of 2009 that resulted in the lowest Aquifer water levels since the District was formed in 1987, and the 2011 drought that produced the driest, hottest single year in Texas history.

3. Hybrid Drought – a synthetic 7-year drought that was defined for this HCP and that combines springflows from the DOR and the RSD on a month-by-month basis, with DOR springflows weighted twice those of the RSD. The District considers this the worst drought reasonably expected to occur during the 20-year term of the ITP.

Figure 5-5 shows the recurrence (nonexceedance) frequency of springflow over the 97-year period of record as it would exist under each of the three groundwater management scenarios. The benefit of the HCP pumping scenario, with measures to avoid, minimize, and mitigate take, compared to the pre-HCP pumping scenario is particularly noticeable at springflows less than about 30 cfs, when adverse effects occur.

Similarly, the District related measured DO concentrations associated with the various combined springflows using linear regression analysis to develop the nonexceedance frequency of DO concentration for springflow under each of the three management (pumping) scenarios. Each outlet has its own DO concentration-springflow relationship, and therefore nonexceedance frequency is outlet-specific. The one for Main Springs is shown in Figure 5-6 as an example; the ones for the other two perennial outlets are similar and are in Appendix J.

Figure 5-7 focuses on the springflow variations that would result from the three groundwater management scenarios during the severe drought conditions of a DOR recurrence and as they relate to the 30- and 20-cfs thresholds for estimating take.

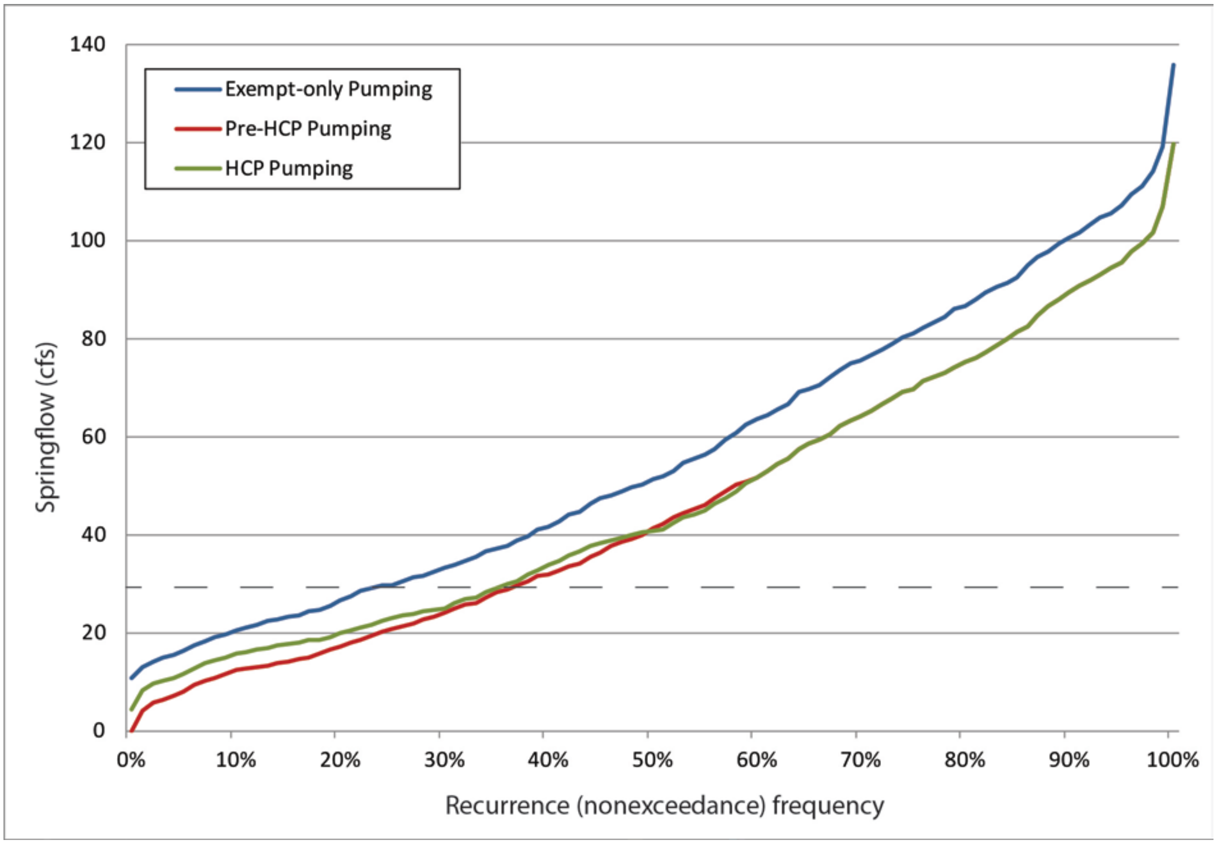


Figure 5-5: Recurrence (nonexceedance) frequency of Barton Springs flow for the period of record under three groundwater management scenarios.
The effect of the HCP conservation measures becomes increasingly more beneficial compared to the pre-HCP scenario as flows less than about 30 cfs (dashed line) continue to decrease.

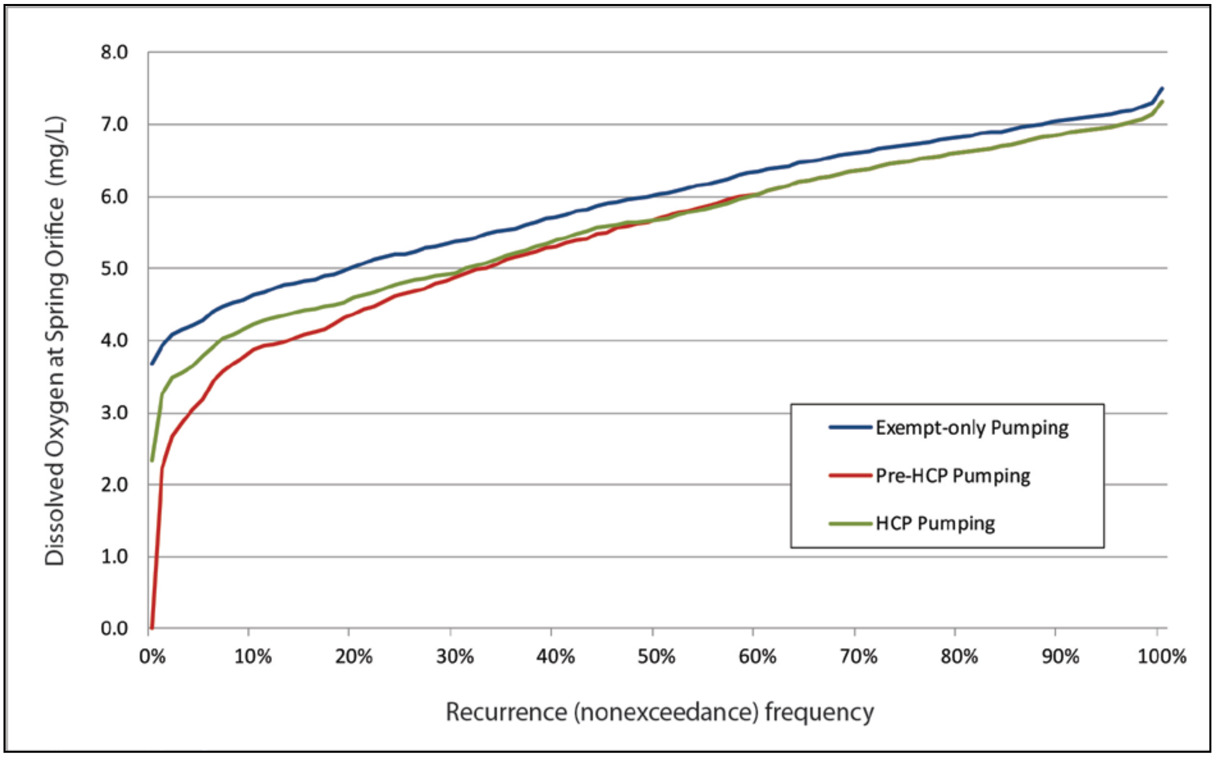


Figure 5-6: Nonexceedance frequency for dissolved oxygen concentration for the period of record at Main Springs under three groundwater management scenarios.
The HCP measures reduce the frequency of low DO concentrations and associated degree of harm that result from nonexempt pumping.

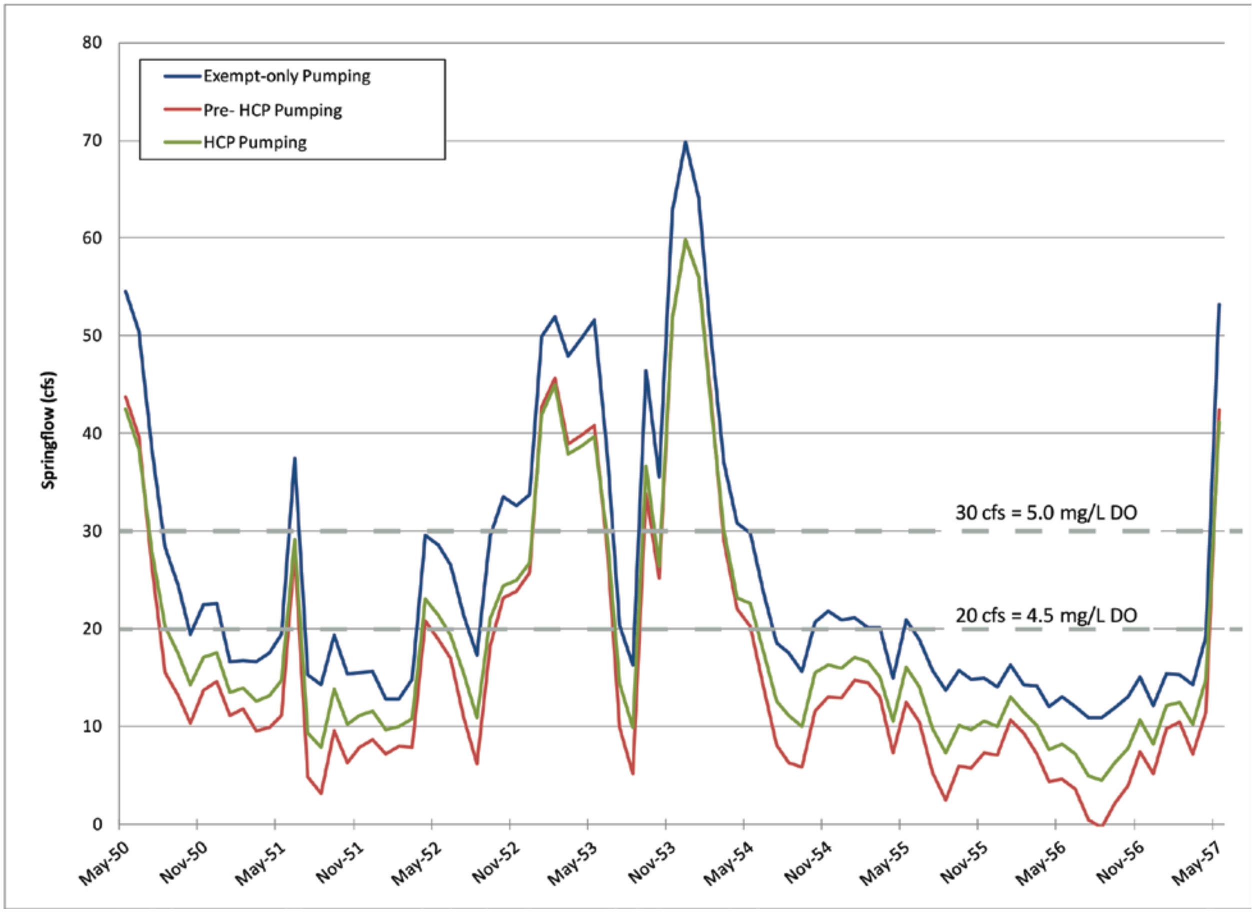


Figure 5-7: Modeled Barton Springs flow during DOR conditions under three groundwater management scenarios.
The relationships between flow under each management scenario and the 30- and 20-cfs thresholds important to take estimates are indicated. In the deepest parts of very severe drought, springflow resulting from each of the three scenarios is below the 20-cfs threshold.

The concept and rationale used to estimate take and develop the monthly "take factor" are illustrated in Figure 5-8 and Table 5-9. The end of the DOR was selected as a discrete worst-case drought scenario to estimate the total take and then to derive the monthly take factor. Full implementation of the HCP measures is assumed, but without DO mitigation measures and benefits of the City's HCP activities. Best professional judgment was used to define the circumstances that relate to estimated take associated with this drought scenario, as outlined below:

Circumstance A: As combined springflows decrease to about 40 cfs, Upper Barton Spring ceases flowing. Withdrawals hasten the cessation of flow and loss of habitat; therefore 100% of the stipulated population of 18 Barton Springs salamander (BSS) is taken owing to the Covered Activities. The take could be considered mostly sub-lethal, primarily annoying and harassing, rather than harming the species. No Austin blind salamander (ABS) are considered to have habitat at Upper Barton Spring.

Circumstance B: Springflow equal to or below 30 cfs (DO concentration ≤ 5.0 mg/L) and above 20 cfs (DO concentration > 4.5 mg/L) may result in a behavioral response from the

Covered Species. Withdrawals hasten springflow decrease; therefore, 100% of the stipulated population of the BSS (821) and ABS (1,000) are taken owing to the Covered Activities. The take could be considered mostly sub-lethal, primarily annoying and harassing, rather than harming the species.

<u>Circumstance C</u>: Springflow decreases to 20 cfs or below (DO concentration ≤ 4.5 mg/L), which may result in a physiological response from the species. This part of the drought is where the more adverse effects on the entire stipulated population are likely to occur due to the duration and low springflow and DO concentration. Covered Activities contribute to but are not solely responsible for low springflow and DO concentration that result in physiological responses that annoy, harass, and ultimately harm the Covered Species. To apportion the take attributable to the Covered Activities, the ratio of permitted pumpage under the HCP conservation program to the total discharge for the 35-month period was used. Permitted HCP pumpage for the 35-month period was 4.8 cfs; total discharge for the 35-month period was 16.7 cfs. Accordingly, about 29% of the stipulated population for each species is taken owing to the Covered Activities. Average DO concentration for Main Spring during this 35 month period (spreadsheed model which includes HCP measures) is about 3.7 mg/L.

The total take for this reference drought period in Figure 5-8 is estimated to be 1,077 BSS. That number is then divided by the period when flow was below the take-initiation threshold (30 cfs), 37 months for the reference drought period. The resulting take for the BSS is 29.1 incidents per month below 30 cfs. The same method and logic used for the ABS results in a take factor of 34.9 incidents per month below 30 cfs. The difference in take factor between species is due to the difference in stipulated populations and the absence of an ABS population at Upper Barton Spring.

The take factor is a conservative approach to estimating the potential incidents of take due to the Covered Activities for future drought scenarios. The factor integrates complicated factors to provide a simple, yet systematic approach to measuring, monitoring, and reporting incidents of take going forward.

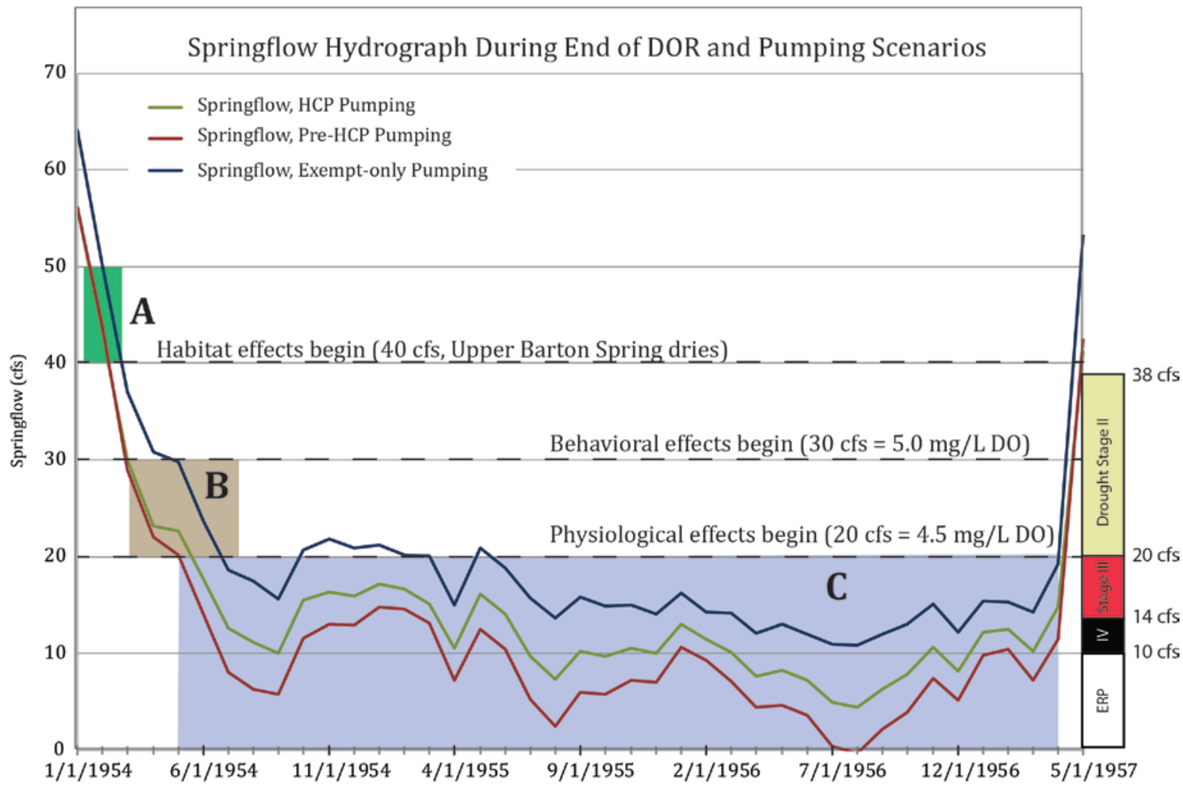
Table 5-9: Derivation of monthly take factors for Covered Species during droughts.

Species	Stipulated Population	Take Circumstance			Total Take	Months Below 30 cfs	Take Factor (monthly below 30 cfs)
		A	B	C			
		Upper BS	Behavioral Effects	Physiological Effects			
BSS	821	18	821	29% x 821 = 238	1,077	37	29.1
ABS	1,000		1,000	29% x 1000 = 290	1,290	37	34.9

BSS = Barton Springs salamander; ABS = Austin blind salamander.

Monthly "Take Factor" Logic Diagram

We conservatively estimate total incidents of take from a 37-month period at the end of the Drought of Record. During the springflow recession we qualitatively estimate take relating to various habitat, behavioral, and physiological effects and thresholds. From this discrete drought a monthly take factor was developed to estimate potential monthly take each time springflows is less than 30 cfs (~5.0 mg/L DO), the take initiation threshold.



A B C

Estimated BSS take (for 37 mo DOR) = 18 + 821 + (821*29%) = 1,077/37 mo = 29.1 BSS/mo

A: Entire stipulated population at Upper Barton Spring experiences mostly sub-lethal take because pumping hastens drying of habitat.

B: Springflow ≤30 cfs (≤ 5.0 mg/L DO): Up to 100% of the stipulated population potentially experiences take because decreased DO from pumping causes adverse behavioral effects that are mostly sub-lethal during these two months.

C: Springflow ≤20 cfs (≤ 4.5mg/L DO): Up to 29% of stipulated population potentially experiences take because decreased DO from pumping contributes to the adverse physiological effects ranging from sub-lethal to lethal as the depth and duration of drought increases. 29% derived from ratio of average permitted pumping to average total discharge over the 35months (4.8 cfs/16.7 cfs = 29%). Note: average DO at Main Springs for the period is 3.7 mg/L.

Take Factor to be used to estimate potential take of the BSS each month springflow is ≤30 cfs, the take initiation threshold.

Figure 5-8: Diagram showing reference period and logic used for computing the monthly take factor.

This 3-year period, deep in the DOR, provided a long-term, consistent basis for differentiating take from other adverse effects during the key periods of severe droughts.

5.2.3.3 Cumulative Take Estimates

Incidents of take over the entire term of the ITP will depend on the drought conditions that occur over the 20-year period. The following cumulative scenario is proposed as a basis for assessing and estimating cumulative take during the ITP term:

1. One 7-year period of Extreme Drought, equivalent to the DOR;
2. One7-year period of Exceptional Drought, equivalent to the Hybrid Drought;
3. Three (3) years of non-severe drought, in which the Covered Species populations recover to their stipulated populations as modeled initial conditions (Table 5-9), and the only take that occurs, nominally each drought year, is to the population at Upper Barton Spring; and
4. Three (3) years of no drought, where no take of any form occurs at any outlet.

This cumulative take scenario is just one possible scenario for a 20-year period, but it is, in the judgment of District hydrogeologists, a very conservative worst-case scenario. In this scenario, the two 3-year periods are interchangeable and the two 7-year drought periods are interchangeable, so the order doesn't matter. This is because the District makes an assumption that either of the 3 years of no drought or non-severe drought is long enough for the Covered Species to rebound to the initial condition used in the model. However, the COA's continuing low census counts after the recent severe drought period that ended in 2011 suggest that at least some if not all outlets may need more time for their populations to recover. The slow recovery and continued low abundance numbers may also be exacerbated by other factors not related to springflow and/or not caused by the District HCP's Covered Activities, and therefore not considered take.

This scenario yields cumulative take estimates for the Barton Springs salamander and the Austin blind salamander shown in Tables 5-10 and 5-11, respectively. The tables show the number of individual incidents of take for each by the Covered Activities over the 20-year ITP term with the HCP conservation measures in place.

Table 5-10: Summary of cumulative take of Barton Springs salamander for 20-year ITP term.

Drought/Springflow	No. Months below 30 cfs	Take/Month	Total Take
3 Years above 20 cfs	12	29.1	349.2
7-Year Hybrid	44	29.1	1,280.4
3 Years above 40 cfs (no drought)	0	0	0
7-Year DOR	72	29.1	2,095.2
Cumulative Total for ITP			**3,725**

Table 5-11: Summary of cumulative take of Austin blind salamander for 20-year ITP term.

Drought/Springflow	No. Months below 30 cfs	Take/Month	Total Take
3 Years above 20 cfs	12	34.9	418.8
7-Year Hybrid	44	34.9	1,535.6
3 Years above 40 cfs (no drought)	0	0	0
7-Year DOR	72	34.9	2,512.8
Cumulative Total for ITP			**4,467**

The actual amount of take incurred in any multi-year drought scenario will depend, other factors equal, on the actual initial size of the populations when the drought period begins. Because the species populations are typically variable, the take could be less than the amount shown, as the initial conditions used in this analysis are a best estimate corresponding to stipulated population sizes at or near the top of a cycle. The distribution of take with time during the 7 years of the severe droughts will depend on the variability of annual meteorological and hydrological conditions. It is no more likely that the take will be spread evenly across the 7-year time span than it will occur over 1 or 2 years in that span.

The effect of the activities covered by the COA's ITP, including specifically its Barton Springs Pool HCP conservation measures, must also be considered in the District's cumulative take estimate and impact assessment, and in the Biological Opinion by the Service. The COA's covered activities are mostly scheduled recurring activities subject to postponement or cancellation during periods when the Covered Species are under duress from natural or anthropogenic causes. While also subject to annual limits, the total cumulative take during the COA's 15-year ITP is 38,365 Barton Springs salamanders and 1,025 Austin blind salamanders, reflecting the recurring, frequent, episodic, and to some extent discretionary covered activities associated with the Barton Springs Pool HCP. The District's cumulative take estimates for its Covered Activities, which are continuous and largely non-discretionary, are 3,725, or 10% and 4,467, or 436% of the COA's cumulative take of Barton Springs and Austin blind salamanders, respectively. (The disparity in take between the species is because the COA's activities cause take of only incidental numbers of Austin blind salamanders in the surface environments of the outlets, rather than in both the surface and subterranean environments as the District's Covered Activities potentially do.)

The COA's and the District's take estimates are not likely to be completely contemporaneous and cumulative. At times when the District's take and its impact are maximum, the COA is likely to have suspended, postponed, or canceled its pool maintenance operations under the terms of its HCP/ITP (although recreational activities may continue), and the COA's take at those times will be near a minimum. Further, the mitigation measures the COA has committed to will benefit the Covered Species even though not all of its covered activities are underway. The District and the COA will strive to minimize cumulative impacts and formalize respective commitments and needed actions in the prospective Memorandum of Understanding/Interlocal Agreement (MOU/ILA) between the two agencies.

5.2.3.4 Considerations for "No Appreciable Reduction" Analysis

The effects of incidental take associated with the Covered Activities must not appreciably reduce the likelihood of the survival and recovery of the Covered Species in the wild—that is, cause jeopardy, per the Service's ITP issuance criteria (Section 2.3.2, Findings for the Service to Issue an ITP). Jeopardy occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the field is appreciably reduced. The analysis of jeopardy is referenced to baseline conditions that include incidental take of the same species from other activities under any other HCP as well as the avoidance, minimization, and mitigation measures associated with it.

As severe droughts deepen the form of take changes from principally sub-lethal to lethal as DO concentration decreases. The phenomenon of decreasing DO concentration is characterized in detail in Appendix J and only highlighted in this section. Estimates of low DO concentration associated with the Covered Activities and drought are shown in Figures 5-9 and 5-10. For the Hybrid Drought in Figure 5-9, DO concentration reaches 4.0 mg/L at Main Springs for 3 months during a 7-year drought period.

Impacts associated solely with natural flows and exempt-only pumping increase substantially as the droughts deepen and become more extreme. Figure 5-10, depicting a recurrence of the DOR, shows that DO concentration with the HCP measures, including DO re-aeration from spring-run improvements (a measure of the Barton Springs Pool HCP) and DO augmentation (a mitigation of this HCP), is not much different than DO concentration without the Covered Activities (exempt-only pumping). Figure 5-10 shows that DO concentration with the HCP measures including DO re-aeration from spring-run improvements and DO augmentation (dashed line in Figure 5-10) matches or exceeds the DO concentration of the exempt-only pumping scenario—indeed, the average DO concentration for both pumping scenarios during the DOR is 4.8 mg/L. However, during the months of lowest springflow (July and August 1956), the scenario of HCP pumping including DO re-aeration from spring-run improvements and DO augmentation results in DO concentration about 1 mg/L below that of the exempt-only pumping scenario. However, the model conservatively correlates flow and DO concentration (Porras, 2014) and assumes only modest gains from DO augmentation of about 0.5 mg/L. The conservatively low DO concentrations and assumed modest gains from DO augmentation reinforce the importance of the conservation measures in avoiding, minimizing, and mitigating decreases in DO and accompanying take.

Because, as suggested in Figure 5-10, the pre-HCP management scenario represents a dire adverse situation for the Covered Species, possibly including extirpation, any groundwater management measures that minimize or mitigate take such that the situation is less adverse than it otherwise would be should not generally be considered to appreciably reduce the likelihood of survival and recovery of the species. This assertion is germane *even if those beneficial actions otherwise might jeopardize survival and recovery of the species*. The HCP for the Edwards Aquifer Recovery Implementation Plan (EARIP) in the San Antonio segment of the Edwards Aquifer reached a similar conclusion.

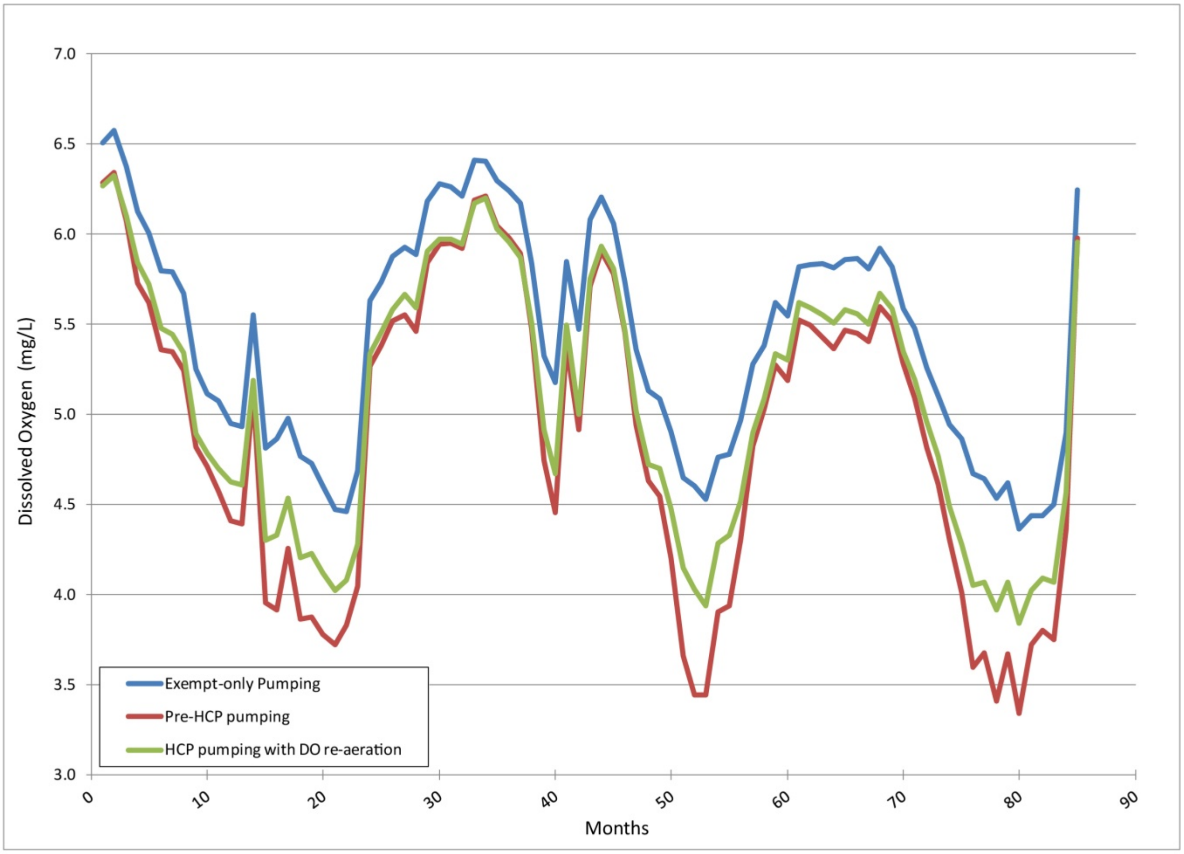


Figure 5-9: Dissolved oxygen concentrations at Main Springs during prolonged, severe (Hybrid) drought under three groundwater management scenarios.

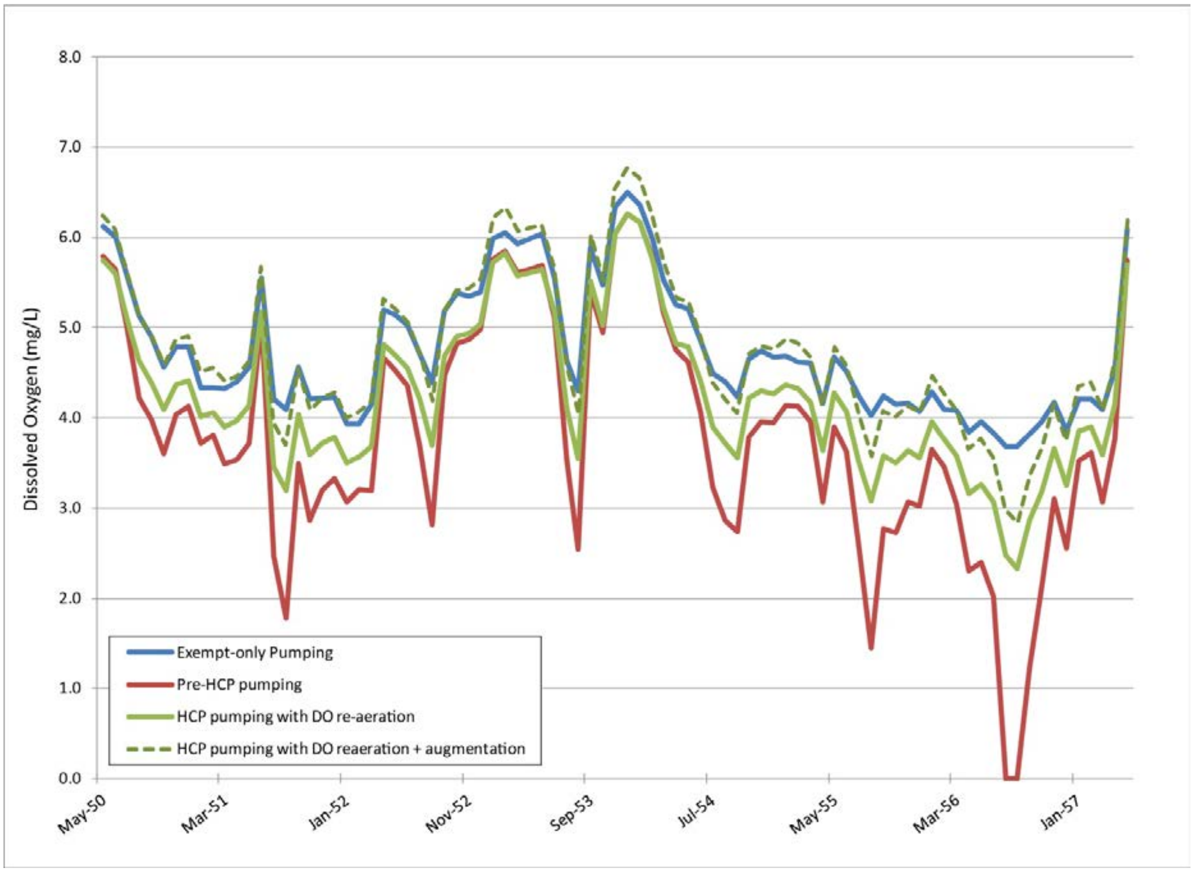


Figure 5-10: Dissolved oxygen concentrations at Main Springs during DOR conditions under three groundwater management scenarios and proposed mitigation measures.
The solid HCP line takes into account planned DO re-aeration from spring-run improvements (+0.3 mg/L), and the dashed HCP line illustrates the effect of a modest amount of DO augmentation (+0.5 mg/L) as proposed mitigation, improving estimated DO concentration relative to that of the exempt-only pumping scenario.

This HCP has noted elsewhere the many uncertainties, assumptions, and stipulations required in making a quantitative take estimate for the Covered Species by the Covered Activities. Several of these in particular bear on the likelihood of an appreciable reduction in survival and recovery:

<u>Probabilities of recurrence of the modeled droughts</u> – The take estimate includes modeling of both a reasonable worst-case drought scenario for the 20-year ITP term (the Hybrid Drought) and an unreasonable worst-case drought scenario for the ITP term (the DOR). It is considered very unlikely that the adverse effects in the modeled cumulative scenario would occur during the ITP. However, an severe drought such as the DOR, while not considered *per se* a reasonable basis for take estimates, could be considered part of an assessment of jeopardy. But the DOR has an estimated recurrence frequency of 100 years. The 7-year reference droughts (Section 5.2.3.2, Apportionment of Take to Adversely Affected Populations) used in this HCP have the following probabilities of occurrence during the 97-year period of record used by the District in calculating recurrence frequencies:

Recent Severe Drought (2005–12)	57%
Hybrid Drought	11%
Drought of Record (1950–57)	1%

The likelihood that the Hybrid and DOR droughts would occur in any single 20-year period within the 97-year period of record is much smaller even than those shown. In particular, it is so unlikely that there will be a DOR recurrence in any given 20-year period that its improbability must be taken into account when judging the likelihood of the risk of an appreciable reduction in survival and recovery.

<u>Migration of animals to less-stressful parts of the habitat</u> – The modeling used for estimating take purposefully included only minimally the reasonable likelihood that, but unquantifiable extent to which, both species would migrate to areas adjacent to the outlets where DO concentration was higher and thus DO-related stress lower. It seems reasonable that some portion of the Austin blind salamander population will move from the immediate vicinity of the outlets where DO concentration is depressed to adjacent connected areas within the Aquifer, especially to subterranean areas at or near the water table, where the atmospheric interface results in generally higher DO concentration (Lazo-Herencia et al., 2011). In addition, the proposed DO augmentation project that is a conditional mitigation measure may provide supplemental benefits in the vicinity of the outlets. For the Barton Springs salamander, the benefit from re-aeration created by the planned but not yet available spring runs and by the conditional DO augmentation that is a potential mitigation measure has also been conservatively estimated in the cumulative loss evaluations. Sensitivity analyses done for this HCP, indicated in the results shown in Figure 5-10 and in Appendix J, suggest that the benefits to the salamander population of relatively small amounts of DO stress relief are disproportionately large, especially the mitigation provided by DO augmentation.

<u>Benefit of evolutionary life-history strategies</u> – The Covered Species have population characteristics and individual organism traits that appear to represent more an "opportunistic" life-history strategy than an "equilibrium" life-history strategy[16]. Some opportunistic population characteristics include relatively large swings in population sizes over multiple-generation time periods, rather than smaller fluctuations around a mean that is a defined "carrying capacity;" rapid growth and development of individual organisms; numerous offspring at a time; reproduction that is more or less continuous if environmental conditions are not limiting; and lack of post-natal and parental care (which otherwise would emphasize and promote better competition by a few individual offspring rather than depending on a "numbers game"). Such characteristics connote evolutionary development of the Covered Species in response to frequent occurrences of disturbances like droughts and floods in their springflow-dominated environment. Floods and droughts cause indiscriminant, density-independent mortality and then recovery of the residual population based on the availability over time of resources in their habitats (Pianka, 2000). Opportunistic species generally may accommodate larger adverse effects related to constrained resources (such as low DO concentration, within limits) that governed their evolution without jeopardizing the species more than could equilibrium species.

[16] The terms "opportunistic" and "equilibrium" have been used as short-hand descriptors for a complex set of evolutionary life-history causative factors that in reality are not uniformly opportunistic or equilibrium, and/or that may differ for different life-stages. A more mechanistic demographic framework includes interactions among age-specific mortality, density-dependent regulation, predation risk, as well as density-independent factors such as extrinsic mortality, resource availability, and environmental fluctuations (Reznick, et al., 2002). A model of this framework accounting for these many interactions for the Covered Species is not available.

This aspect of the populations of the Covered Species may have been a key to the survival of the species during multiple prolonged and severe droughts through the millennia, and therefore to avoiding jeopardy. The pre-eminent dendrochronologist for the HCP area, Dr. Malcolm Cleaveland, recently noted, "When you study the historic record [as revealed by tree-ring data], you see there were multiple ten-year droughts worse than the so-called '50s DOR. There was a period in the 1500s and another in the late 1600s that make the 1950s look wet. You are going to have at least one major drought every century if you study the data." (Rivard, 2014).

In the long run, all of these factors are believed to work against an appreciable reduction in the likelihood of survival and recovery of the Covered Species during the ITP term, which, as noted at the beginning of this section, is one of the ITP issuance criteria.

5.3 Impact of Take on Covered Species Populations

5.3.1 Assessment of Population Impacts

This section summarizes the findings and conclusions of the District concerning take and mortality, and assesses the consequences of take on the Covered Species populations. There is considerable duplication of information presented in previous subsections and the appendices, as this is intended to be a stand-alone section.

The Covered Species are subjected on a recurring basis to highly variable springflow, and during periods of low flow, to naturally small DO concentrations that correlate directly with springflow at the individual outlets. During such periods, data show the number of individuals observed diminishes, which is likely due to a combination of mortality of individuals (population reduction) and migration to areas in and near the spring outlets that are less accessible for observation. The periods of low springflow during drought are followed by extended periods of much-higher-than-average springflow and the rapid return of DO concentration to more normal ranges. The epigean (surface-dwelling) Barton Springs salamander population increases substantially during the flow-recovery periods after an apparent lag period of about 6 months. The amount and rate of increase differ among the individual spring outlets and are also dependent on the timing of droughts relative to one another (City of Austin, 2013). Rebound has been significantly retarded after the most recent droughts at all outlets but especially at Old Mill Spring. It is difficult to discern an overall trajectory with time for the robustness of the population of either species; it varies naturally with the time step selected and drought conditions, upon which groundwater withdrawals are superimposed. Some COA biological staff have recently hypothesized that the salamander population(s) may have established a new, smaller equilibrium, with a lower average size about which the population fluctuates more restrictedly (City of Austin, 2013). This would constitute a rapid shift away from a population with more opportunistic life-strategy characteristics toward one with more equilibrium life-strategy characteristics.

Responses of organisms to chemical stressors are inherently linked to the magnitude, frequency, and duration with which organisms are exposed to the stressor(s) (Newman, 2009). For the Covered Species, data indicate that DO stress represents the primary factor influenced by the District's activities. But there is only a limited amount of protection with respect to DO for the Covered Species from regulatory institutions. In Texas, surface water quality standards are intended to protect aquatic life and uses of surface-water bodies, and DO water quality criteria for high aquatic life use is historically defined by either lotic (rivers and streams) or lentic (lakes and reservoirs) habitats (Brooks et al., 2008). For example, a 24-hour DO-concentration minimum (3 mg/L) that does not last longer than 8 hours and a 24-hour minimum mean (5 mg/L) during a 24-hour period is used for lentic systems (TCEQ, 2003). However, habitats supporting the Covered Species are neither river nor lake, but aquifer, spring runs, and spring-fed pools. The current (2014) understanding of the oxygen requirements of the Covered Species (Woods et al., 2010) does not allow for a confident determination of whether existing DO criteria and standards are adequate to protect these spring-fed habitats. Similarly, in spite of the innovative investigations and management practices associated with the District's HCP, the protections provided by the HCP measures are also uncertain.

This is not an unusual circumstance. Environmental assessments of stressor-response relationships for threatened and endangered species are consistently limited by lack of experimental data for the covered species. In such cases, use of surrogate species is common owing to limited availability of protected species. Because closely related species are not necessarily common, the U.S. Environmental Protection Agency (USEPA) developed the Web-based Interspecies Correlation Estimation (Web-ICE) to assist with such efforts (http://www.epa.gov/ceampubl/fchain/webice/). Unfortunately, data for aquatic salamanders in this software are not available, which prevented its application for the Covered Species. Further, before initiation and development of this HCP, a quantitative understanding of DO stress on *Eurycea* (including the Barton Springs and Austin blind salamanders) and other salamanders was poorly understood. Thus, to assess the suitability of San Marcos salamander to serve as a surrogate for Barton Springs salamander, a laboratory stressor-response study was done to define metabolic rate relationships between Barton Springs and San Marcos salamanders (Woods et al., 2010). Owing to these metabolic rate data and also genetic and life-history similarities between those two species (Chippindale, et al., 2000), San Marcos salamander was selected as a surrogate species for DO stressor-response studies of relevance to the Covered Species (Woods et al., 2010). Use of this surrogate species for assessing take impacts on the Barton Springs salamander in particular seems well founded.

Survival and growth responses to stressors have high relevance to the population level of biological organization[17] and are thus routinely used as measures of effect to support ecosystem protection goals defined in ecological risk assessments (Suter, 2006). For DO, an adverse outcome pathway (AOP) framework can be used to examine stress caused by hypoxia (low DO concentration) and resulting impacts to individuals and populations of Covered Species (Figure 5-11). This AOP illustrates the large amount of information required to make confident judgments of stressor-response impacts in real-world settings but which for the most part does not exist for the Covered Species; at the same time, it indicates specific areas of additional research.

To examine responses to DO concentration by a surrogate species, Woods et al. (2010) identified mortality and growth DO thresholds during a 28-day study with adult and a 60-day study with juvenile San Marcos salamander, respectively. As described in Section 5.2.1, Experimental Assessment of Salamander Responses to Changes in Water Chemistry Related to Springflow, the 60-day NOAEL (No Observed Adverse Effect Level) for juvenile growth is 4.4 mg/L and the 28-

[17] Population (of a species) is one level in the hierarchy of biological matter, from simplest (atom) to most complex (biosphere).

day LC_5 estimate for adult mortality is 4.5 mg/L. (LC [Lethal Concentration]$_5$ is the exposure concentration in which 5% of the organisms die.) These thresholds from Woods et al (2010) appear to represent the best data available for DO stress to any aquatic salamander and thus provide a reasonable foundation for interpreting DO risks to the Covered Species. Nevertheless, these thresholds are the result only of controlled laboratory-based research investigations, not extensive field investigations.

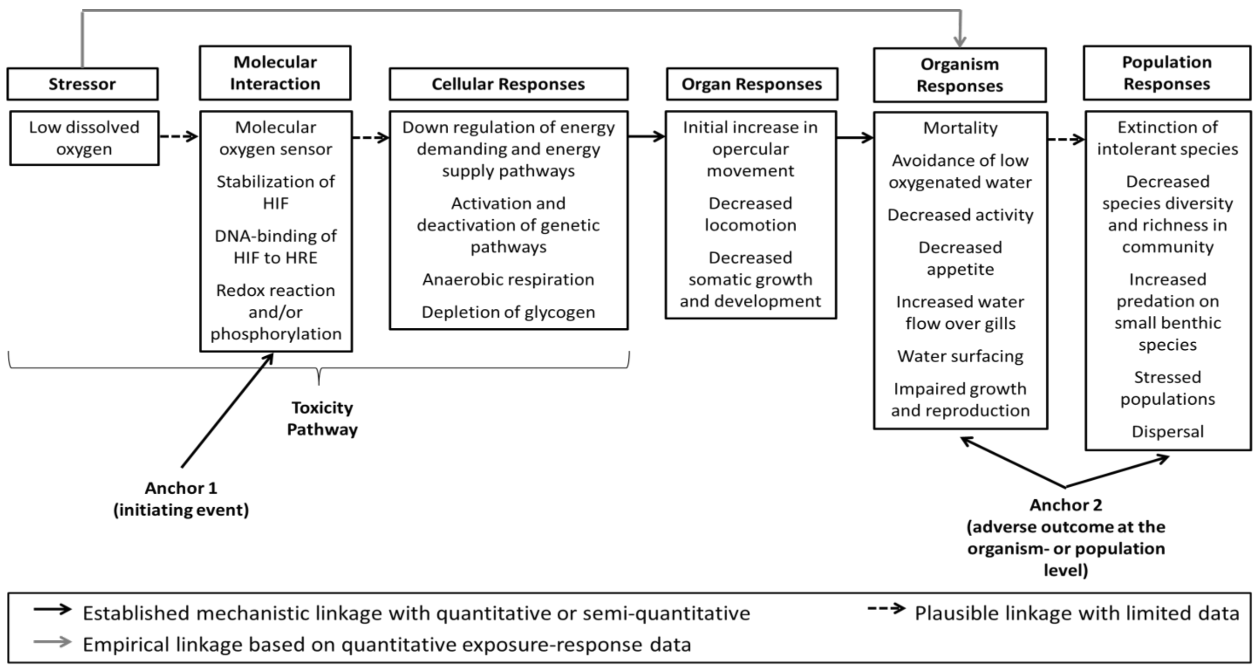


Figure 5-11: A proposed adverse outcome pathway (AOP) in the Covered Species for dissolved oxygen.

This AOP represents a conceptual model linking a molecular initiating event to adverse effects at higher levels of biological organization. Source: Modified from Saari and Brooks (2013).

The scientific investigations and analyses done for this HCP indicate that salamander populations are not adversely affected physiologically by DO concentrations of 4.5 mg/L or greater, and are only mildly affected by DO concentrations slightly lower, at 4.2 mg/L. The salamander populations appear rather well-adapted to variability in DO concentrations above this level, although some behavioral changes have been observed, which is not unexpected in this circumstance. Using available field and experimental data and inference, the lethal form of take is indicated to begin for a small portion of the population at a springflow of about 20 cfs, which over the 97-year period of record would have occurred about 9% of the time even without any nonexempt pumping (that is, without the Covered Activities). If DO concentration decreased to 3.9 mg/L for an extended period, lethal take as individual salamander mortality could be noticeable and of concern. If DO concentration decreased to less than 3.4 mg/L, the situation could be dire for individual salamanders, and if prolonged *without the mitigation proposed in this and the Barton Springs Pool HCPs*, dire for the population and recovery of the Covered Species. Given the ecological setting and the population characteristics, take under the District HCP must be inferred rather than directly observed, and the flow-duration relation (percentage of time springflow is equaled or exceeded) for Barton Springs is a rational proxy for DO concentration in assessing take in this HCP.

In addition to the physiological-related direct and indirect effects of DO reductions on the Covered Species, another potential source of incidental take is the small reductions in the wetted habitat area that might otherwise be attributable to the Covered Activities ("small" especially relative to habitat reductions attributable to "natural drought" conditions). However, the COA's ongoing habitat restoration is not yet implemented, which precludes the District from describing quantitatively the "new" wetted habitat; the new wetted habitat will form a new baseline condition for the District's HCP. Thus it is not possible to assess how much, if any, of the new habitat could be changed by withdrawal-induced springflow reductions at the reconfigured perennial springs during severe drought. These effects would likely be more important to a dominantly density-dependent equilibrium species than to these species, where habitat size is less of a concern than habitat conditions. As noted, the additional wetted habitat and re-aeration provided by re-establishing the spring runs would also tend to offset any concerns for the Covered Species arising from drought-induced wetted habitat loss, if any, at the perennial spring outlets.

The measures now proposed under the HCP are more protective of springflow than any of the previous alternative management scenarios; and they are believed to be the most protective that can be applied under current law and with the current state of knowledge. Nevertheless, during a recurrence of the DOR and under the District's most stringent withdrawal-curtailment program, springflows expressed in cfs will likely be in the mid-to-high single digits, which would be unprecedented in the historical record. The DO concentrations of such springflows and the level of salamander mortality and disruption of salamander life activities associated with a recurrence of the DOR are unknown; but they probably would be appreciable without mitigation, which underscores the importance of the proposed mitigation measures. The desired future condition (DFC) of ensuring that springflow during a DOR recurrence is no less than 6.5 cfs has been established by the District as its primary groundwater management objective, representing a balance among various risks and uncertainties and also curtailments that are at the maximum extent practicable. The proposed HCP conservation measures intended to minimize and mitigate take and to avoid jeopardy are reasonably expected to achieve that objective.

There is much variability and uncertainty in this ecological system, as suggested by the AOP of Figure 5-11 and as discussed next in Section 5.3.2, Uncertainties in Take and Impact Evaluations. The variability and uncertainty preclude making conclusive determinations regarding effects on organisms and impacts on populations on the basis of empirical observations of the Covered Species. Nevertheless, the District HCP implements management and conservation measures based on sound science that are intended to reduce risks of DO stress to the Covered Species, particularly risks associated with naturally occurring severe droughts.

5.3.2 Uncertainties in Take and Impact Evaluations

The estimates of take are considered useful approximations that are based on a number of assumptions and stipulations to account for uncertainties. Many of the more important of these uncertainties have been discussed in various preceding subsections. They and others are summarized below, in no particular order, in one place in this document, to facilitate identification and appreciation of their scope and significance to the take estimates and ultimately the avoidance-of-jeopardy determination.

Effect of All Recharge Sources on Aquifer Water Level Declines

The groundwater modeling described in Section 3.2.2.1.2, Sources and Implications of Variation in Springflow at Barton Springs, may not have explicitly included the effects of all significant sources of groundwater recharge on the recession of Aquifer water levels during severe drought. Recent information suggests that the 1:1 correspondence between withdrawals and springflow, on which the springflow analysis in this HCP is based, may be less than 1:1 during severe drought; that is, one unit of withdrawal might result in less than one unit of reduction in springflow. This uncertainty is conservative toward springflow and its calculated DO concentrations, but the actual DO concentrations associated with declining water levels during severe drought are unknown.

Springflow Recurrence Frequencies for Other Than Monthly Means

The natural flows of Barton Springs as well as aggregate withdrawals change very slowly during a prolonged, severe drought. Recurrence (nonexceedance) frequencies for monthly mean flows would be very similar to weekly mean or even daily mean flows. As discussed in Section 3.2.2.1.2, Sources and Implications of Variation in Springflow at Barton Springs, actual flows expressed as shorter than monthly flow durations would tend to decrease the percentage of time flow is below a designated rate for the smaller durations because the changes would be derived primarily from storms that, over short-term durations, increase springflow.

Likely Differences Between Authorized and Actual Pumpage by Permitted Groundwater Users

The relationship between withdrawals and springflow that was modeled for the HCP was based on use of the entire authorized amount each month by each permittee, which is a conservative assumption in the HCP. Even though curtailments during drought are more likely to increase the fraction of curtailed use represented by actual use, the District's recent experience in drought management indicates that actual use is still below the authorized curtailed use otherwise permitted (Figure 3-9).

Springflow-related Factors Other Than DO Concentration

The District's Covered Activities—that is, managed withdrawals from the Aquifer—can only affect those physical and chemical habitat factors directly related to springflow. Of these, only DO was modeled, inasmuch as the quantitative influence of other factors, other than temperature, has not been established. Temperature variations are controlled less by springflow and more by seasonality or the number of high stormflows in springflow (Mahler and Bourgeais, 2013), neither of which are controlled by the Covered Activities. Prolonged drought tends to reduce temperature variation in springflow. Concentrations of ionic constituents do exhibit some variation with springflow, but even the highest constituent concentrations are well within the freshwater range and vary over a relatively narrow range of about 100 mg/L TDS (Herrington and Hiers, 2010). Poteet and Woods (2007) examined the effects on adult salamanders over a much wider range of salinity and found no behavioral response. No studies are known that attribute physiological or behavioral changes to the small observed variations in salinity of spring flows for either adult or non-adult life stages of the Covered Species."

Covered Species Population Size and Distribution

Because of their cryptic nature, spending an appreciable part of their time in subterranean or otherwise inaccessible surface habitats, the population sizes of both Covered Species have not been firmly established. This is especially pertinent to the Austin blind salamander, for which only a small part of its Critical Habitat is observable.

For the Barton Springs salamander, the population sizes at the outlets are based on the mean-plus-one SD metric that has been used in the COA's approved Barton Springs Pool HCP for estimating such take. For each outlet, their distribution will vary indeterminately with time and water chemistry conditions.

The population size of the Austin blind salamander is simply unknown. It was inferred on the basis of observed density of subterranean salamander species in surface environments in both Barton and San Marcos Springs, adjustment for areal distribution of presumed habitat-supporting conduits and fissures at the water table, and then extension to the Critical Habitat size. This approach involves substantial uncertainty in the overall population size, as the incidental surface density may not be representative of the subterranean density for such subterranean species; and also because the known habitat of other, similar subterranean salamanders is more than two orders of magnitude larger (EARIP, 2012) than the Critical Habitat-designated area for Austin blind salamander.

Another related assumption that was made for both species has to do with the DO concentrations to which they are exposed and where those concentrations occur. The indicated DO concentration at the spring outlets was applied to the entire existing populations for both species. The District believes that an unknown but likely substantial fraction of the Barton Springs salamander population will move away from the surface outlet to water that has higher DO concentrations, although how much higher is also unknown. The re-establishment of accessible spring runs ("daylighting") at the outlets of Eliza Spring and Old Mill Spring will, among other things, re-aerate the water and provide a driving force for such migration. Similarly, an unknown but likely substantial fraction of the Austin blind salamander population will either exist normally or move into the subsurface away from the outlet once DO concentrations decrease to stressful levels, seeking subterranean areas with a greater proportion of unconfined water that has higher DO concentrations. It is not reasonable to assert that the entire population of either of these mobile species will continue to be exposed to the same DO concentrations at the outlet when DO stress is high and less stressful environments with higher DO concentrations are readily accessible to at least a portion of those populations. A rather conservatively small amount of such DO relief is included in the analyses used in this HCP. The District considers it likely that salamander migration to areas of higher DO concentration when under stress from low DO concentration may well be a primary mechanism that has allowed these endemic species to have persisted through many and more-severe droughts during their natural history. However, this tendency to migrate, its areal extent, the proportion of the populations involved, and the degree of stress relief provided are all unknown and presently indeterminate. These unknowns are likely the focus of future research.

Indirect Effects of Withdrawals on Other Species Important to the Covered Species

The take estimates in this HCP are based on habitat changes as they relate directly to the Covered Species themselves, not on the macroinvertebrate community on which the salamanders rely for prey (City of Austin, 2013). For example, the effect of depressed DO concentration at low springflow on the size of and predator-avoidance behavior of the population of amphipod or other prey in the habitat has not been evaluated. The District is unaware of a *quantitative* relationship between springflow or DO concentration and the macroinvertebrate prey that could be compared to the effects on the salamander species. In essence, the District is making an assumption that the macroinvertebrates either are present in sufficiently large population numbers that they are not a limiting factor for the salamanders, or they are not impacted physiologically by low DO concentration to the same extent as the Covered Species, or both. The validity of this assumption is unknown, but it introduces uncertainty that can only be judged qualitatively. The COA has noted that some 100 taxa of macroinvertebrates have been catalogued at the outlets, and while the abundance of the macroinvertebrate community decreases with decreasing springflow, the decreases are not uniform across the entire community (City of Austin, 2013). Such diversity would be beneficial to the predator Covered Species. Furthermore, the Covered Species are known as invertevores, which means that they do not discriminate as to what species of invertebrates become their prey, an adaptation that is especially useful in energy production and conservation during drought. Nevertheless, the relationship of springflow, DO concentration, and macroinvertebrate abundance and diversity may be important to cumulative impacts and could be a worthwhile focus of future research, although extreme low flows would be required for meaningful evaluation in the field.

Non-modeled Differences Between the Two Covered Species

Notwithstanding the differences in population sizes and their locations, for the most part the two Covered Species are considered to react and behave similarly, in absence of data to the contrary. However, the Austin blind salamander is in a separate evolutionary branch from the Barton Springs salamander, and also the San Marcos salamander that was used in the laboratory studies (City of Austin, 2013), so its similarity in DO stress-response to the Barton Springs salamander is not assured. In fact, it seems to spend a substantially greater part of its life in environments of naturally lower DO concentration than the Barton Springs salamander; so it could be reasonably asserted that the Austin blind salamander might be better adapted genetically to such environments. Because the existence, direction, and magnitude of differences in mortality relative to DO concentration for the two species are indeterminate, no difference in the Austin blind salamander's mortality from that of the Barton Springs salamander is assumed in the modeling; which the District suggests may tend to overstate the Austin blind salamander's mortality at a given DO concentration. Other assertions could be made that no differences are known to exist and that lack of data requires no difference to be imputed.

Lack of Data on DO Concentration Variations at Extreme Low Flows

The relationship between springflow and DO concentration was defined for each outlet by regression equations based on paired observations of springflow and DO concentration at each outlet. There were very few pairs with flow below 20 cfs and no pairs with flow below 14 cfs. Flows below 20 cfs constitute the zone of most interest to salamander physiology and behavior. Relying solely on trends established by data at higher flows is problematic and introduces additional uncertainty into the modeling (but see immediately below).

Differences in DO Concentration Among Individual Spring Outlets

Whether and what trends actually exist between DO concentration and springflow and how they differ among the outlets under extreme low-flow conditions is currently indeterminate, as springflow has not been extremely low since DO measurements were begun. The markedly different low-flow water chemistry observed at Old Mill Spring compared to that at Eliza and especially Main Springs, along with its emergence along a different fault (Hauwert, 2009; Johns, 2006), suggest that Old Mill Spring might have a fundamentally different springflow-DO concentration relationship. Old Mill Spring was modeled using the same type of regression equation as the other two perennial outlets, even though the hydrogeologic setting could indicate a different selection. Statistically, there is no basis to judge what regression relationship(s) should be used (Porras, 2014; Turner, 2007).

Effect of DO Concentration Variations on Other Life Stages

Funding limitations required the laboratory study in this HCP to focus on the life stages of the salamander typically encountered. Most of the stressor-response study addressed adult salamander stages, with a limited investigation of DO stress to juveniles. Although adult stages may be the lengthier stages and therefore adults are exposed to the largest variations in DO concentration, the effect of DO-concentration variations on egg and larval forms is also potentially important but unaccounted for in this HCP. However, no known data or studies suggest that the Covered Species are especially susceptible to such variations of the magnitude introduced by the Covered Activities. This may be an area for future research.

Differences Between Predicted and Observed DO Concentrations

The DO concentrations predicted by the regression equations on total springflow systematically deviated from the DO concentrations actually measured for recent drought springflows by 0.6 mg/L, with the measured DO concentrations higher than those predicted (Turner, 2009). Some of the deviation may be within the variability and error associated with statistical manipulations. Porras (2014) indicates by statistical analysis that the variability and error may be on the order of ±0.2 mg/L. Some of the deviation might be from the use of one outlet for DO measurement but all outlets in aggregate for developing the regression relationship; or simply from the randomness and variability of any individual environmental event (in this instance, the 2008–09 drought). But generally, the deviation suggests that some of the uncertainties mentioned in this section, such as the absence of extreme low-flow DO data and regression relationships that are consequently skewed, are in fact conservatively accommodated in the HCP; and that actual effective DO concentration is higher than predicted and used in the take estimate.

Application of Laboratory Data to In-the-Field Conditions

Section 5.2.1.3, Implications and Limitations of Stressor-Response Study, discussed the uncertainties in laboratory studies of natural biological systems, noting that the response of test organisms under controlled conditions may not be the same as the response in the field.

Cumulative Risk Factors beyond the District's Control

Adverse effects on the Covered Species resulting from anthropogenic water quality changes—for example, nonpoint-source pollution arising from watershed modification—may be exacerbated by or additive, synergistic, or antagonistic to adverse effects from springflow-related water chemistry changes such as DO-concentration variations. These adverse effects may have significant consequence to the Covered Species, but the District has no control over the existence or magnitude of such factors, so those cumulative effects have not been considered in the take estimate *per se*, in accordance with the Service's guidance. Rather, the impacts of these sources of additional risk are to be addressed in the environmental impact statement prepared by the Service under the National Environmental Policy Act (NEPA) for this HCP.

The sources of uncertainty and variation discussed in this subsection notwithstanding, the District is reasonably confident that the take estimates developed herein provide a relative sense of the overall benefit of the proposed HCP conservation measures. On the basis of the recent severe drought conditions, the District suggests that in aggregate the take estimates are conservatively high. In practice, using these estimates is believed to provide a buffer of additional protection.

5.3.3 Comparison with Take Impact Assessment in EARIP

The Final HCP for the San Antonio segment of the Aquifer by the Edwards Aquifer Recovery Implementation Program (EARIP, 2012) covers a very large area and addresses many listed species and many activities. It includes *Eurycea* salamander species that are quite similar to the two Covered Species in this HCP; managed groundwater withdrawals are one of its Covered Activities as in this HCP; and its HCP conservation measures are supported in part by the groundwater regulatory program of one of its implementing parties (Edwards Aquifer Authority), as is the District's regulatory program in this HCP. The EARIP HCP was recently approved and an ITP issued by the Service in 2013. Generally, the bases for the take impacts and for the Service's findings as to jeopardy related to the groundwater regulatory program in the EARIP HCP and to those similar species should be consistent. In that regard, the similarities and differences between the two HCPs are noted:

- The EARIP acknowledges the uncertainties associated with life requirements of its salamander species in relation to springflow. In fact, it related the minimum flow requirements for its salamander species to those of a listed plant species; and documented that this flow requirement was supported by the rough approximations established by the Service in the early 1990s for gauging take and jeopardy for these salamander species at Comal and San Marcos Springs. While these thresholds incorporated the best science then available for evaluating take and jeopardy of the salamander species, the Service acknowledged then that significant data gaps existed, requiring a more conservative approach and the mandatory use of professional judgment to a greater degree than usual in setting the take and jeopardy thresholds. However, even though substantially more information and site-specific data exist today, the EARIP did not propose different thresholds for the listed salamander species. The Service developed the original thresholds on a rather quick-response basis as an outcome of federal litigation concerning groundwater regulation in the San Antonio segment, and no analogous thresholds exist for the Barton Springs segment. In their absence, and on the basis of data and science now available, this HCP proposes new groundwater-management thresholds that are specifically designed to protect salamanders at Barton Springs to the greatest extent practicable.

- The EARIP acknowledged that the indeterminate size of the actual total populations and the uncertainties as to factors affecting their natural variability confounded quantitative take estimates and impact analysis, necessitating use of assumptions and professional judgments. This HCP does the same. The ITP for the EARIP authorizes take of 263,857 San Marcos Salamanders. By comparison, this HCP estimates potential maximum take of 3,725 Barton Springs Salamanders and 4,467 Austin blind salamanders, about 1% and 2%, respectively, of the EARIP ITP.

- The EARIP concluded that the uncertainty that existed about the impact of small springflows of varying durations on the salamander species precluded definitive statements as to the amount of take and its impacts. It essentially assumed that maintenance of continuous springflow at least above the lower of the Service's older, general thresholds (along with protection of water quality from pollution) would enable the species to survive a repeat of DOR-like conditions. This HCP expresses similar concerns about the uncertainties in evaluating take and population impacts, even though using the new thresholds developed as part of this HCP and evaluating adverse effects were informed by specific springflow-DO concentration statistical relationships.

- The EARIP's take analysis for these species primarily focused on physical habitat changes and related effects caused by surface activities, which its participating entities can control. It did not quantitatively evaluate hydrochemical effects, such as changes in DO concentration and salinity, on salamander behavior and physiology related to springflow as is done in this HCP, which is the only aspect that the District can control.

- The EARIP essentially assumed that the subterranean species would retreat into the Aquifer even if springflow ceased and would generally not be adversely affected by small springflows, although potential risk associated with take was assumed qualitatively to increase at flows below the Service's older lowest-flow threshold. This HCP reaches a similar conclusion but supports it with a novel quantitative analysis of effects on organisms over time and impacts on populations.

- The EARIP, which is designed to be a phased program, used a 15-year initial term for its ITP, while this HCP is a non-phased program and proposes a 20-year term.

- The EARIP included in its cumulative take analysis a 7-year DOR recurrence plus 8 "average" years for its ITP term. This HCP not only includes a 7-year DOR recurrence, but also a 7-year Exceptional Drought (the Hybrid Drought), plus 3 less-severe drought years and 3 non-drought years in its cumulative take analysis for the ITP term. Barton Springs is at a lower elevation than any spring in the San Antonio segment of the Aquifer and thus is the regional base outlet for the entire Edwards Aquifer, including the San Antonio segment; although DOR springflows at Barton Springs are smaller, the recurrence interval of DOR springflows at Barton Springs is likely longer (that is, smaller frequency of occurrence) than those at the higher-elevation springs addressed by the EARIP.

- The EARIP asserted that the uncertainties associated with the qualitative analyses for these species highlight the necessity of applied research, expanded biological and water quality monitoring, and ecological modeling, and that those future developments will be factors in assuring that the species are not jeopardized. This HCP does the same.

The analyses and assessments of the salamander species in both HCPs are best characterized as qualitative, with quantitative approximations only and with some significant uncertainties that are not readily accounted for or overcome. On the basis of the best science available and reasonable assumptions and stipulations, both HCPs conclude that the proposed conservation measures are necessary and sufficient to minimize take to the maximum extent practicable and to avoid jeopardy.

6.0 Conservation Program

The District is seeking a Section 10(a) Incidental Take Permit (ITP) to cover use of the Aquifer as a water supply and management of the Aquifer by the District's regulatory program related to permitted withdrawals from the Aquifer (Covered Activities). Everything that the District does relates to responsible groundwater use and to management of the aquifers in its jurisdiction, including the Aquifer. By design, all District activities are intended to directly or indirectly benefit the Aquifer and therefore the habitats of the Covered Species, especially compared to the unregulated pumping conditions that would exist without the District's management efforts. So the Covered Activities integrate the conservation measures for the Covered Species. However, these activities will not completely avoid or prevent take of the species all the time, rather minimize and mitigate the take as it occurs, so the ITP is being sought to accommodate those circumstances.

As a groundwater conservation district (GCD) in Texas, these activities are derived from and authorized by inclusion in the District Management Plan (MP), and the District Rules. The District cannot legally perform any activities, not even conservation activities, that are not authorized by statute (Texas Water Code Chapter 36, or the District's enabling legislation codified as Special District Local Laws Code Chapter 8802) *and* also that are not at least implicitly a part of the prevailing MP. The legal authority for the Rules & Bylaws (BSEACD, 2012) that compose the District's regulatory program flows directly from the statutes under which the District operates and from the MP.

The MP must be reviewed; revised as needed to accommodate new information, priorities, and statutory requirements; re-adopted; and approved by the Texas Water Development Board (TWDB) at least every 5 years. The current (2014) MP was most recently revised and approved by the TWDB on January 7, 2013. It will require review and re-adoption no later than November 2017. The current MP largely anticipates and includes the statutory-enabled regulatory authorities needed for the initial set of the proposed District Habitat Conservation Plan (HCP) measures described below; other measures that might be used to achieve planned objectives may or may not require additional authorities; a substantially revised set of measures in the approved HCP could necessitate an earlier-than-planned MP revision and re-adoption. This duality in authorities illustrates that the measures committed to in the HCP and the requirements of the MP are intertwined: Future revisions to the MP must honor the commitments and requirements of the HCP once approved, and the HCP's current measures and future adaptive measures are restricted to those that are authorized by statute and by the prevailing approved MP.

In addition, the District may carry out its statutory powers and responsibilities to amend rules from time to time and substitute alternative requirements for reduction in withdrawals and/or alternative practices, procedures, and methods for promoting increased groundwater levels. Such rulemaking is an anticipated part of the District's function as a regulatory agency. However, any rule amendments must not reduce the effectiveness of the restrictions on withdrawals described in the District HCP and incorporated in the ITP to protect springflow, unless the HCP and ITP are also amended.

6.1 Biological Goals and Objectives of HCP

The biological goals and objectives of the District HCP are established in recognition of (a) the direct relationship between the volume of water in the Aquifer and the hydrochemistry of the natural discharge from the Aquifer as springflow, and (b) the life requirements of the Covered Species with respect to dissolved oxygen (DO) concentrations of the groundwater as it is discharged from the Aquifer.

The biological goals of the District HCP are to:

- Minimize drought-related decreases in size and health of the Barton Springs salamander population to greatest extent practicable,
- Minimize drought-related decreases in size and health of the Austin blind salamander population to greatest extent practicable, and
- Promote recovery of the populations from those decreases to levels required for their long-term viability.

The following objectives, supported by the impact analysis described in Section 5.2, support the HCP in pursuit of these overarching goals:

- Adopt and implement groundwater-management measures to minimize the areal extent, concentration range, and time duration that springflow-dependent DO concentration at the spring outlets is 3.3 mg/L or less under all Aquifer conditions;
- Adopt and implement groundwater-management measures to maintain minimum springflows that a consensus of a knowledgeable scientific advisory panel indicates correspond to DO concentrations with a 10-day average of at least 3.9 mg/L during all but Extreme Drought conditions; and
- Adopt and implement groundwater-management and related measures that do not cause other natural water chemistry parameters to exceed their historical ranges under all Aquifer conditions.

These objectives as they relate to managing groundwater withdrawals are believed to be consistent with the best scientific information currently available and within the District's statutory authorities for groundwater management. Their implementation is integrated directly into the operating conservation and management programs, policies, and rules of the District, thus indicating a commitment to their achievement.

Specific measures to accomplish these objectives are discussed in detail in the following section. These measures, both individually and in aggregate, represent the best attainable legal plan of the District to conserve the species and are designed to correspond with the scope of the HCP. The District believes these measures substantially improve the probabilities that all of these objectives are achieved throughout the life of the ITP.

6.2 Minimization and Mitigation Measures

The key to conserving and minimizing take of the Covered Species is maintenance of adequate habitat and ambient conditions to provide the necessary life requirements for the species. This goal can be accomplished (1) if external factors beyond the District's control (for example, substantial increases in oxygen-demanding material from point-source and nonpoint-source pollutants in runoff) do not determine habitat quality; (2) if the measures in the COA's HCP for Barton Springs Pool afford the designed protection during recreational use and maintenance of the pool; and (3) if the management of the Aquifer as proposed in this District HCP protects and maintains springflow sufficient to provide minimum acceptable habitat consistent with those life requirements.

As mentioned previously, the nature of the Covered Activities is inconsistent with the avoidance of take in an absolute sense. However, the minimization and mitigation measures that have been established by the District reduce groundwater withdrawals during the key Extreme Drought period to an amount that is about the same as existed when the District was formed and when an unfettered, vested property right attached to such withdrawals (about 5 cfs, as described in Section 4.1.2, Historical Perspective of Covered Activities). In this sense, the District's groundwater management program proposed herein not only minimizes take during all drought conditions, but during the most critical period for the Covered Species, avoids the take associated with all withdrawals begun after the District was established and its regulatory program began.

6.2.1 Direct HCP Measures

The conservation measures that will be undertaken directly by the District under the HCP to conserve the Covered Species, by minimizing and/or, under prescribed conditions, also mitigating take to the greatest extent possible, are identified and discussed in this section of the HCP. Because these measures are integral to the District as an operating GCD, they are discussed in categories that correspond with the overarching *statutory* goals for all GCDs in Texas. The numerical order of these goals in the subsections below conforms to their listing in statute, not in the order of importance to the HCP. These measures are now supported as District-specific objectives or performance standards in the District's 2013 MP. Taken together, they compose the "Enhanced Best Attainable Alternative" for the HCP that is the embodiment of the District's own, internal adaptive management process, as discussed in section 6.4, District HCP Adaptive Management Process. All of these measures are currently authorized and being done or, for a few, will be initiated as of the issuance of the ITP. They include both ongoing (currently authorized and continuously operating, as warranted) and episodic avoidance/minimization measures. By design and as required by law, they provide a necessary balance between maximizing the amount of groundwater available for use and conserving and protecting the groundwater resource, including Covered Species protection.

During the 20-year term of the ITP, it is envisioned that some changes to these measures will be required or prudent, but unless the underlying ITP permit is amended, the effect of any changes to the measures will be at least as, if not more, protective of the Covered Species by reducing attendant incidental take.

The following subsections describe the direct minimization measures proposed by the District in its HCP. Other, indirect conservation measures, including research and mitigation measures, are identified and discussed in the Section 6.2.2, Other HCP Measures and Strategies. Section 6.2.3, Summary of HCP Measures to Minimize and Mitigate Take, contains a synopsis of the HCP program, including a summary table of HCP commitments.

6.2.1.1 Providing Most Efficient Use of Groundwater

This goal encompasses actions that assure the relevant statutory, regulatory, scientific, administrative, and education dimensions of the District programs promote a balance between the least consumption of groundwater for each type of use and the benefits of using groundwater for those uses. Such efficiency optimizes on a continuing basis using groundwater as a water supply and preserving, conserving, and protecting the groundwater resources for future uses, including as endangered species habitat. Therefore, all measures under this goal are ongoing Minimization Measures except 1-3, which is chiefly an adaptive prelude to adjusted minimization.

- HCP Measure 1-1: Provide and maintain on an ongoing basis a sound statutory, regulatory, financial, and policy framework for continued District operations and programmatic needs.

- HCP Measure 1-2: Monitor aggregated use of various types of water wells in the District, as feasible and appropriate, to assess overall groundwater use and trends on a continuing basis.

- HCP Measure 1-3: Evaluate quantitatively at least every 5 years the amount of groundwater withdrawn by exempt wells in the District to ensure an accurate accounting of total withdrawals in a water budget that includes both regulated and non-regulated withdrawals, so that appropriate groundwater management actions are taken.

- HCP Measure 1-4: Develop and maintain programs that inform and educate citizens of all ages about groundwater and springflow-related matters, which affect both water supplies and salamander ecology.

6.2.1.2 Controlling and Preventing Waste of Groundwater

This goal encompasses functions related to ensuring that all groundwater that is withdrawn from wells is used beneficially, and that activities that may cause or contribute to wasteful use of groundwater and to the pollution or harmful alteration of the groundwater resource are prevented. Only reasonable demand for beneficial use can be authorized through the permitting process, and no well is allowed to waste groundwater, including allowing the commingling of poor-quality and high-quality groundwater. For the HCP, measures under this goal minimize the amount of groundwater withdrawn without purpose or reasonable use and that allows subsurface deterioration of the reservoir, and thereby maximizes high-quality springflow for salamander habitat. Therefore, all measures under this goal are ongoing Minimization Measures.

- HCP Measure 2-1: Require all newly drilled exempt and nonexempt wells and all plugged wells to be registered and to comply with applicable District Rules, including Well Construction Standards.

- HCP Measure 2-2: Ensure permitted wells and well systems are operated as intended by requiring reporting of periodic meter readings, making periodic inspections of wells, and reviewing pumpage compliance at regular intervals that are meaningful with respect to the existing aquifer conditions.

6.2.1.3 Addressing Conjunctive Surface Water Management Issues

This goal promotes measures and policies that use joint surface water-groundwater systems effectively, without imposition of adverse quantity or quality impacts on either the surface or groundwater resource. In the context of the HCP, conjunctive use is alternative water use in lieu of using the fully subscribed Edwards resource as a water supply and that allows for needed pumpage curtailments, especially during Extreme Drought. The District may be able to undertake certain of these activities directly, either on its own or as part of a partnership, thereby providing a potential model or framework by which its permittees could undertake such actions.

- HCP Measure 3-1: Assess the physical and institutional availability of existing regional surface-water and alternative groundwater supplies and the feasibility of those sources as viable supplemental or substitute supplies for District groundwater users. <u>This is an ongoing Minimization Measure that is an adaptive prelude to a Research Measure and possibly a Mitigation Measure.</u>

- HCP Measure 3-2: Encourage and assist District permittees to diversify their water supplies by assessing the feasibility of alternative water supplies and fostering arrangements with currently available alternative water suppliers. <u>This generally is an ongoing Minimization Measure, but depending on the specific arrangements pursued, it could also be an episodic Minimization Measure</u>.

- HCP Measure 3-3: Demonstrate the importance of the relationship between surface water and groundwater, and the need for implementing prudent conjunctive use through educational programs with permittees and public outreach programs. <u>This is an ongoing Minimization Measure</u>.

6.2.1.4 Addressing Natural Resource Management Issues

This goal focuses on protecting the natural resources of the Aquifer and of other aquifers within the District's jurisdiction, including not only the groundwater of those aquifers but also soils and agriculture; air quality; economic resources such as sand and gravel and oil and gas; and the flora and fauna dependent on them, including endangered species. By using sound science to increase the understanding of the natural resource systems, including relationships with underlying and overlying water-bearing rocks and up-gradient surface waters, and to delineate the impacts associated with the amount and location of pumping, recharge, and discharge, appropriate and acceptable policies and rules can be developed and effective regulatory decisions can be made by the District.

- HCP Measure 4-1: Assess ambient conditions in District aquifers on a recurring basis by (1) sampling and collecting groundwater data from selected wells and springs, (2) conducting scientific investigations to better determine groundwater availability for the District aquifers; and (3) conducting studies to help increase understanding of the Aquifer and, to the extent feasible, detect possible threats to water quality and evaluate their consequences. This is an ongoing Minimization Measure that is also an adaptive prelude to a Research Measure and possibly a Mitigation Measure.

- HCP Measure 4-2: Evaluate site-specific hydrogeologic data from applicable production permits to assess potential impact of withdrawals to groundwater quantity and quality, public health and welfare, contribution to waste, and unreasonable well interference. This is an ongoing Minimization Measure.

- HCP Measure 4-3: Implement separate management zones and, as warranted, different management strategies to address more effectively the groundwater management needs for the various aquifers in the District, particularly the Aquifer. This is an ongoing Minimization Measure.

- HCP Measure 4-4: Actively participate in the joint planning processes for the relevant aquifers in the District to establish and refine Desired Future Conditions (DFCs) that protect the Aquifer and other aquifers and the Covered Species. This is an ongoing Minimization Measure that is an adaptive prelude to an episodic Minimization Measure.

6.2.1.5 Addressing Drought Conditions

This goal involves developing and implementing policies that effectively manage groundwater drought conditions in the Aquifer. The regulation of withdrawals and their curtailment during drought, especially during prolonged severe drought, is the principal institutional minimization tool that allows the otherwise lawful pumping of the Aquifer to occur while being protective of the Covered Species. For example, now the only permits available to withdraw water from the Aquifer are Conditional Production Permits, which is an interruptible supply that is subject to complete cessation of pumping during drought and is issued only if an alternative supply is available. All these are ongoing Minimization Measures, although during severe drought, the step-wise implementation of increasingly stringent curtailments of water withdrawals could also be considered episodic Minimization Measures; over time they also would inform an adaptive outcome.

- HCP Measure 5-1: Adopt and keep updated a science-based drought trigger methodology and frequently monitor drought stages for the Aquifer on the basis of actual aquifer conditions, and declare drought conditions as determined by analyzing data from the District’s defined drought triggers and from existing and such other, new drought-declaration factors, especially the prevailing DO concentration trends at the spring outlets, as warranted.

- HCP Measure 5-2: Implement a drought management program that step-wise curtails Aquifer use to at least 50% by volume of currently (2014) authorized aggregate monthly use during the Extreme Drought stage, and that designs/uses other programs that provide an incentive for additional curtailments where possible (for example, cap-and-retire of historical production permits; accelerated and/or larger severe drought curtailments in exchange for additional authorized use during non-drought periods).

- HCP Measure 5-3: Inform and educate permittees and other Edwards Aquifer well owners about the significance of declared drought stages and the severity of drought and encourage practices and behaviors that reduce water use by a stage-appropriate amount.

- HCP Measure 5-4: Assist and, where feasible, incentivize individual historical-production permittees in developing drought planning strategies that foster compliance with implemented District drought rules, including step-wise demand curtailment by drought stage to at least 50% of currently (2014) authorized use, on a 3-month rolling average basis, during Extreme Drought; “right-sizing” authorized use over the long term to reconcile actual water demands and permitted levels; and as necessary and with appropriate conditions, the substitution by surface water, reclaimed water, and/or other groundwater resources such as the Trinity Aquifer to achieve curtailments.

- HCP Measure 5-5: Implement a Conservation Permit that is held by the District and accumulates and preserves withdrawals from the Aquifer that were previously authorized with historic-use status and that is retired or otherwise additionally curtailed during severe drought, for use as ecological flow at Barton Springs during Extreme Drought and thereby increase springflow for a given set of hydrologic conditions.

6.2.1.6 Addressing Demand Reduction through Conservation

This goal encompasses all activities that strive to reduce consumption of groundwater of the Aquifer by educating District stakeholders about water conservation and extraordinary demand-reduction measures. This initiative provides tools by which all end-users of the Aquifer can preserve springflow and the quality of habitat of the Covered Species, as well as Aquifer water levels in wells, by reducing per-capita water use during non-drought periods as well as episodically during severe drought. <u>These are primarily ongoing Minimization Measures once developed, although the temporary demand reductions during drought that are enabled here have an episodic Minimization aspect as well</u>.

- HCP Measure 6-1: Develop and maintain programs that inform, educate, and support District permittees in their efforts to educate their end-user customers about water conservation and its benefits, and about drought-period temporary demand reduction measures.

- HCP Measure 6-2: Encourage use of conservation-oriented rate structures by water utility permittees to discourage egregious water demand by individual end-users during declared drought.

- HCP Measure 6-3: Develop and maintain programs that educate and inform District groundwater users and constituents of all ages about water conservation practices and resources.

6.2.1.7 Addressing Supply through Structural Enhancement

This goal encompasses various structural activities—typically, engineered solutions that are undertaken by the District directly to increase the amount of water in the Aquifer over that which would otherwise be available. By increasing the water in storage and by providing means to increase supply, either at all times or during certain times, impacts of drought can be less frequent, less severe, and of shorter duration, springflows can be preserved, and endangered-species habitat impairment can be minimized. These are generally adaptive preludes to Research Measures and Mitigation Measures, as the ability to implement them varies with knowledge and with time; but to the extent they are used, they have as well either <u>ongoing</u> or episodic Minimization dimensions, or both.

- HCP Measure 7-1: Improve recharge to the Aquifer by conducting studies and, as feasible and allowed by law, physically altering (cleaning, enlarging, protecting, diverting surface water to) discrete recharge features that will lead to an increase in recharge and water in storage beyond what otherwise would exist naturally.

- HCP Measure 7-2: Conduct technical investigations and, as feasible, assist water-supply providers in implementing engineered enhancements to regional supply strategies, including desalination, aquifer storage and recovery, and effluent reclamation and re-use, to increase the options for water-supply substitution and reduce dependence on the Aquifer.

6.2.1.8 Quantitatively Addressing Established Desired Future Conditions

This goal involves developing, supporting, monitoring, and keeping updated the adopted DFCs for the Aquifer that protect water-well yields in the more vulnerable parts of the Aquifer and protect springflow, and consequently of the Covered Species. The DFCs for the Aquifer provide the statutory and regulatory basis, in the consensus of all GCDs in the State's Groundwater Management Area (GMA)10, for mandatory curtailments of withdrawals and aggregated firm-yield caps on withdrawals and increases in recharge so that the DFCs are achieved. The DFCs to protect well yields and springflow are considered the most important HCP measures, and all the others are supportive of these two measures; the DFCs are also continuing adaptive management measures, as they are statutorily iterative and re-adopted at least every 5 years. Achieving these two measures is the principal metric for gauging success of the District's groundwater management program and HCP.

- HCP Measure 8-1: As deemed appropriate by the Board, adopt rules that restrict, to the greatest extent practicable, the total amount of groundwater authorized to be withdrawn annually from the Aquifer to an amount that will not substantially accelerate the onset of drought conditions in the Aquifer; this is established as a running 7-year average springflow at Barton Springs of no less than 49.7 cfs during average recharge conditions. <u>This is an ongoing Minimization Measure.</u>

- HCP Measure 8-2: As deemed appropriate by the Board, adopt rules that restrict, to the greatest extent practicable and as legally possible, the total amount of groundwater withdrawn monthly from the Aquifer during Extreme Drought conditions in order to minimize take and avoid jeopardy of the Covered Species as a result of the Covered Activities, as established by the best science available. This is established as a limitation on actual withdrawals from the Aquifer to a total of no more than 5.2 cfs on an average annual (curtailed) basis during Extreme Drought, which will produce a minimum springflow of not less than 6.5 cfs during a recurrence of the drought of record (DOR). <u>This is an episodic Minimization Measure that operates during the most severe stage of drought when the Covered Species are under highest stress</u>.

6.2.2 Other HCP Measures and Strategies

As a complement to the direct HCP measures identified above, the District will apply other measures and strategies primarily to research and mitigate consequences on the Covered Species of groundwater use in the District's jurisdiction. These other measures and strategies, collectively termed "indirect HCP measures" herein, are characterized in this section.

To a substantial extent, these indirect measures require involvement of other parties in addition to the District. Such measures will be further defined and undertaken through available and appropriate mechanisms, which may include grant funding, other external funding, in-kind contributions, partnerships, and negotiation of requisite interlocal and other agreements. In particular, the prospective interlocal agreement (ILA) with the COA offers strategic benefits to the District in applying these indirect HCP measures in multiple ways. Some of these indirect measures may be continuing commitments of in-kind and other resources for a specified beneficial purpose, and others may be participation in various ways for special-purpose projects that are authorized by the HCP but will be subject to future Board approval of scope, funding sources and amounts, and opportunity costs. Although to a considerable extent these indirect measures are HCP-specific, they leverage existing information from other parties and avoid redundant efforts, are consistent with the District's charge to expand the knowledge of the Aquifer, and are beneficial to the District's permittees in helping to acquire a legal shield against assertions of violating the Endangered Species Act (Act).

6.2.2.1 Research Measures

Substantial uncertainties exist concerning a number of factors that at least potentially affect take: the hydrologic performance of the Aquifer, especially during extreme low-flow conditions; the relationship between springflow and its DO concentrations, especially during extreme low-flow conditions; the ecological effects and physiological impacts of antagonistic contaminants in recharge water; and salamander behavior, both individually and as a population, under ecological stress. The Research Measures identified in this subsection are intended to address some of these uncertainties.

- HCP Research Measure R-1: The District from time to time during the term of the ITP will consider working with universities, the COA, and other qualified parties on projects to better inform and determine the level of risk associated with springflow-related changes in water chemistry affecting the viability and recovery of the Covered Species' population, by supporting:

1. Surveys of the temporal and spatial DO variability of the Aquifer and the surface environments around the Barton Springs complex,
2. Continuing the support of laboratory stressor-response studies of salamander species, or
3. Efforts to restore the spring-run habitat to allow improved re-aeration at the spring outlets.

- HCP Research Measure R-2: The District from time to time during the term of the ITP will consider working with the USGS, the TWDB, universities, the COA, Edwards Aquifer Authority, and other qualified parties to:

1. Develop a refined conceptual model to improve the numerical models for the District aquifers, and
2. Improve hydrogeologic characterization of aquifer function during extreme low flows, including assessments of new potential recharge sources from urban recharge and bypasses from the San Antonio segment, and their changes over the term of the ITP.

6.2.2.2 Mitigation Measures

The District recognizes that the proposed conservation program is unable to avoid take at all times. Consequently, it proposes the following Mitigation Measures:

- HCP Mitigation Measure M-1: The District may support the operations of an existing refugium with facilities capable of maintaining backup populations of the Covered Species to preserve the capacity to re-establish the species in the event of the loss of population due to a catastrophic event such as an unexpected cessation of springflow or a hazardous materials spill that decimates the species habitat. Such supplemental support would be provided through a commitment of in-kind, contracted support, and/or cash contributions or other appropriate means of support that would contribute to:

1. Continuing the study of salamander physiology and/or behavior, and/or
2. Conserving field and captive populations.

Commitments of in-kind, contracted support, and/or cash contributions to support the refugium and its research program may be authorized by the Board.

- HCP Mitigation Measure M-2: The District, in cooperation with the COA, will participate in conducting feasibility studies and, as warranted, pilot and implementation projects to evaluate the potential for beneficial subsurface DO augmentation of flow in the immediate vicinity of the spring outlets and improved surface DO augmentation in the outlets (only) during Extreme Drought conditions. In-kind, contracted support, and/or cash contributions, phased during the term of the permit, may be authorized for feasibility studies and, if a project is feasible, for the pilot study and implementation of the augmentation project.

- HCP Mitigation Measure M-3: The District will extend the currently committed time period to operate the Antioch Recharge Enhancement Facility to continue after the 319(h) grant commitments (September 2014 or later), thereby improving recharge water quality and reducing nonpoint-source pollution at the outlets from runoff during that time.

- HCP Mitigation Measure M-4: The District will establish a fund for plugging abandoned wells to eliminate high-risk abandoned wells as potential conduits for contaminants from the surface or adjacent formations into the aquifer, with priority given to problematic wells close to the Barton Springs outlets. The fund would be established within the first year after issuance of the ITP with repurposed seed money currently held in the Drought Reserve Account, which would be re-designated as a new Aquifer Protection Reserve Account. The new account would exist solely to fund plugging of abandoned wells and would be replenished with any collected enforcement penalties and an annual budgeted supplement at the discretion of the Board.

  HCP Mitigation Measure M-5: Throughout the term of the ITP, the District commits to provide leadership and technical assistance to other government entities, organizations, and individuals when prospective land-use and groundwater management activities in those entities' purview will, in the District's assessment, significantly affect the quantity or quality of groundwater in the Aquifer. The District will respond actively and appropriately to legislative initiatives or projects that affect Aquifer characteristics, provided such actions are consistent with established District rules, ongoing initiatives, or existing agreements. (Examples include contesting unsustainable wastewater management or actions that contravene the District's consent decree(s) that are projected to adversely affect the Aquifer, and providing technical support to GMA 9 and other GCDs whose practices may affect the Aquifer.)

6.2.3 Summary of HCP Measures to Minimize and Mitigate Take

A summary of all the direct and indirect measures that constitute the heart of the District HCP is presented in Table 6-1. Each measure is designated as to whether it is a more or less continuously operating Minimization Measure for implementing the HCP, an episodically or periodically implemented Minimization Measure, whether the measure is adaptive in nature, and/or a Research or Mitigation Measure. Taken together, these measures lay out the District's preferred option for the HCP Conservation Measures proposed in this HCP. In addition, the table specifies the applicable performance standard(s) from the District's approved 2013 MP as they correspond to each measure. The applicable performance standards essentially authorize the District to perform that HCP measure, and also provide success metrics (measures of achieved effectiveness) for each standard. The MP, which is revised as necessary and re-approved by the TWDB at least every 5 years, is on the District website, at: http://www.bseacd.org/about-us/governing-documents/.

Table 6-1: Summary of HCP Measures, classification by type, and relation to Management Plan performance standards.

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
1-1	Provide and maintain on an ongoing basis a sound statutory, regulatory, financial, and policy framework for continued District operations and programmatic needs.	●		●	PS 1-3, PS 2-1	
1-2	Register and monitor aggregated use of various types of water wells in the District, as feasible and appropriate, to assess overall groundwater use and trends on a continuing basis.	●			PS 2-3, PS 2-4, PS 3-1, PS 6-1, PS 6-2	
1-3	Evaluate quantitatively at least every 5 years the amount of groundwater used by exempt wells in the District to ensure an accurate accounting of total withdrawals in a water budget that includes both regulated and non-regulated withdrawals so that appropriate groundwater management actions are taken.			●	PS 4-2	Exempt well use is not a managed Covered Activity, but in aggregate potentially affects allowable nonexempt well use

[18] Designates those measures that over time may have an adaptive dimension that affects the implementation of that and/or other conservation measures. It does not refer to measures that are to be pursued using the DOI/FWS Adaptive Management Plan protocol (discussed in Section 6.4, District Adaptive Management Process).

[19] Corresponding Performance Standards designated in the District's 2013 Management Plan, at: http://www.bseacd.org/about-us/governing-documents/

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
1-4	Develop and maintain programs that inform and educate citizens of all ages about groundwater and springflow-related matters, which affect both water supplies and salamander ecology.	●			PS 3-3, PS 4-4	
2-1	Require all newly drilled exempt and nonexempt wells and all plugged wells to be registered and to comply with applicable District Rules, including Well Construction Standards.	●			PS 2-2, PS 2-3 (Existing wells)	
2-2	Ensure permitted wells and well systems are operated as intended by requiring reporting of monthly meter readings, making periodic inspections of wells, and reviewing pumpage compliance at regular intervals that are meaningful with respect to existing aquifer conditions.	●			PS 2-3, PS 2-4, PS 3-1	

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
3-1	Assess the physical and institutional availability of regional surface-water and alternative groundwater supplies, and the feasibility of those sources as viable supplemental or substitute supplies for District groundwater users.			●	PS 5-1	
3-2	Encourage and assist District permittees to diversify their water supplies by assessing the feasibility and availability of alternative water supplies and fostering arrangements with currently available alternative water suppliers.	●	●		PS 5-1	Depending on arrangements, for example, shifts only during severe drought; could also be an Episodic Measure

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
3-3	Demonstrate the importance of the relationship between surface water and groundwater, and the need for implementing prudent conjunctive use, through educational programs with permittees and public outreach programs.	●		●	PS 4-4, PS 5-4	
4-1	Assess ambient conditions in District aquifers by (a) sampling and collecting groundwater data on a recurring basis from selected wells and springs, (b) conducting scientific investigations to better determine groundwater availability for the District aquifers; and (c) conducting studies to help increase understanding of the Aquifer and, to the extent feasible, detect possible threats to water quality and evaluate their consequences.	●		●	PS 6-1 PS4-2 5-1, 5-2, 5-3, 6-2 PS4-2, 5-3, 6-2	Some aspect of this measure is informing adaptive changes for future rulemaking

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
4-2	Evaluate site-specific hydrogeologic data from applicable production permits to assess potential impact to groundwater quantity and quality, public health and welfare, contribution to waste, and unreasonable well interference.	●		●	PS2-2, 2-3, 4-3, 6-2	
4-3	Implement separate management zones, and as warranted, different management strategies to address variable groundwater management needs for the aquifers in the District, particularly the Aquifer.	●			PS 2-1, PS 5-1	
4-4	Actively participate in the joint planning processes for the relevant aquifers in the District to establish and refine Desired Future Conditions that are protective of the Aquifer, other aquifers, and the Covered Species.	●		●	PS 4-2	Ongoing activities related to HCP Measures 8-1 and 8-2

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
5-1	Adopt and keep updated a science-based drought trigger methodology and frequently monitor drought stages for the Aquifer on the basis of actual aquifer conditions, and declare drought conditions as determined by analyzing data from the District's defined drought triggers and from the existing and such other, new drought-declaration factors, especially the prevailing DO trends at the spring outlets, as warranted.	●	●	●	PS 3-2	
5-2	Implement a drought management program that step-wise curtails Aquifer use to at least 50% by volume of currently (2014) authorized aggregate monthly use during the Extreme Drought stage, and that designs/uses other programs that provide an incentive for additional curtailments where possible (for example, cap-and-retire of historical production permits; accelerated and/or larger severe drought curtailments in exchange for additional authorized use during non-drought periods).	●	●	●	PS 3-1, PS 4-2, PS 5-1	

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
5-3	Inform and educate permittees and other Edwards Aquifer well owners about the significance of declared drought stages and the severity of drought and encourage practices and behaviors that reduce water use by a stage-appropriate amount.	●	●	●	PS 3-1, PS 3-3, PS 4-4, PS 5-4	
5-4	Assist and, where feasible, provide individual historical-production permittees incentives to develop drought planning strategies that foster compliance with implemented District drought rules, including step-wise demand curtailment by drought stage to at least 50% of currently (2014) authorized use, on a 3-month rolling average basis, during Extreme Drought; "right-sizing" authorized use over the long term to reconcile actual water demands and permitted levels; and as necessary and with appropriate conditions, the substitution by surface water, reclaimed water, and/or other groundwater resources such as the Trinity Aquifer to achieve curtailments.	●	●	●	PS 3-1, PS 5-1	

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
5-5	Implement a Conservation Permit that is held by the District and accumulates and preserves withdrawals from the Aquifer that were previously authorized with historic-use status and that is retired or otherwise additionally curtailed during severe drought for use as ecological flow at Barton Springs during Extreme Drought and thereby increase springflow for a given set of hydrologic conditions.	●		●	Objective 3, PS 4-5	The outcomes of this goal's other measures produce an adaptive dimension over time
6-1	Develop and maintain programs that inform, educate, and support District permittees in their efforts to educate their end-user customers about water conservation and its benefits and drought-period temporary demand reduction measures.	●	●		PS 3-3, PS 5-4	Increased intensity during severe drought has an Episodic dimension

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
6-2	Encourage use of conservation-oriented rate structures by water utility permittees to discourage egregious water demand by individual end-users during declared drought.	●		●	PS 3-1	Will be a Minimization Measure if/once implemented by water-supply permittees
6-3	Develop and maintain programs that educate and inform District groundwater users and constituents of all ages about water conservation practices and resources.	●	●		PS 5-4	Increased intensity during severe drought has a Mitigation dimension
7-1	Improve recharge to the Aquifer by conducting studies and, as feasible, physically altering (cleaning, enlarging, diverting surface water to, and protecting) discrete recharge features that will lead to an increase in recharge and water in storage beyond what otherwise would exist naturally.	●		●	PS 5-2	Some aspect of this measure is taking place nearly all of the time

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
7-2	Conduct technical investigations and, as feasible, assist water-supply providers in implementing engineered enhancements to the regional supply strategies, including desalination, aquifer storage and recovery, and effluent reclamation and re-use, to increase the options for water-supply substitution and reduce dependence on the Aquifer.	●		●	PS 5-1, 5-3,	Some aspect of this measure is taking place nearly all the time
8-1	As deemed appropriate by the Board, adopt rules that restrict, to the greatest extent practicable, the total amount of groundwater authorized to be withdrawn annually from the Aquifer to an amount that will not substantially accelerate the onset of drought conditions in the Aquifer; this is established as a running 7-year average springflow at Barton Springs of no less than 49.7 cfs during average recharge conditions.	●		●	PS 4-5	Established via the joint planning process of GMA 10, with major but not sole input by the District; statutory adaptive dimension

ID No.	Description	Ongoing Minimization	Episodic Minimization	Adaptive [18]	Management Plan Performance Standards[19]	Comments
8-2	As deemed appropriate by the Board, adopt rules that restrict, to the greatest extent practicable and as legally possible, the total amount of groundwater withdrawn monthly from the Aquifer during Extreme Drought conditions in order to minimize take and avoid jeopardy of the Covered Species as a result of the Covered Activities, as established by the best science available; this is established as a limitation on actual withdrawals from the Aquifer to a total of no more than 5.2 cfs on an average annual (curtailed) basis during Extreme Drought, which will produce a minimum springflow of not less than 6.5 cfs during a recurrence of the drought of record.	●	●	●	Objective 3, PS 4-2, PS 4-5	Established via the joint planning process of GMA 10, with major but not sole input by the District; statutory adaptive dimension

RESEARCH MEASURES				
R-1	The District from time to time during the term of the ITP will consider working with universities, the COA, and other qualified parties on projects to better inform and determine the level of risk associated with springflow-related changes in water chemistry affecting the viability and recovery of the Covered Species' population, by supporting: a. Surveys of the temporal and spatial DO variability of the Aquifer and the surface environments around the Barton Springs complex, b. Continuing the support of laboratory stressor-response studies of salamander species, or c. Efforts to restore the spring-run habitat to allow improved re-aeration of the water at the spring outlets.	●	PS 6-2	
R-2	The District from time to time during the term of the ITP will consider working with the USGS, the Texas Water Development Board, universities, the COA, Edwards Aquifer Authority, and other qualified parties to: a. Develop a refined conceptual model to improve the numerical models for the District aquifers, and b. Improve hydrogeologic characterization of aquifer function during extreme low flows, including assessments of new potential recharge sources from urban recharge and bypasses from the San Antonio segment, and their changes over the term of the ITP.	●	PS 6-2	

MITIGATION MEASURES				
M-1	The District may support the operations of an existing refugium with facilities capable of maintaining backup populations of the Covered Species to preserve the capacity to re-establish the species in the event of the loss of population due to a catastrophic event such as an unexpected cessation of springflow or a hazardous materials spill that decimates the species habitat. Such supplemental support would be provided through a commitment of in-kind, contracted support, and/or cash contributions that would contribute to: a. Continuing the study of salamander physiology and/or behavior, and b. Conserving field and captive populations.	●		Within authority; no related standard; implemented at Board's discretion
M-2	The District, in cooperation with the COA, will participate in conducting feasibility studies and, as warranted, pilot and implementation projects to evaluate the potential for beneficial subsurface DO augmentation of flow in the immediate vicinity of the spring outlets and improved surface DO augmentation in the outlets (only) during Extreme Drought conditions. In-kind, contracted support, and/or cash contributions, phased during the term of the permit, may be authorized for feasibility studies and, if a project is feasible, for the pilot study and implementation of the augmentation project.	●		Within authority, no related standard; implemented at Board's discretion
M-3	Extend the currently committed time period to operate the Antioch Recharge Enhancement Facility to continue after the 319(h) grant commitments (September 2014 or later), thereby improving recharge water quality and reducing nonpoint-source pollution at the outlets from runoff events during that time.		PS 5-2	

M-4	Establish fund for plugging abandoned wells to eliminate high-risk abandoned wells as potential conduits for contaminants from the surface or adjacent formations into the aquifer, with priority given to problematic wells closer to the Barton Springs outlets. The fund would be established within the first year after issuance of the ITP with repurposed seed money currently held in the Drought Reserve Account which would be re-designated as a new Aquifer Protection Reserve Account. The new account would exist solely to fund plugging of abandoned wells and would be replenished with any collected enforcement penalties and an annual budgeted supplement at the discretion of the Board.			Within authority; no related standard; implemented at Board's discretion
M-5	Throughout the term of the ITP, the District commits to provide leadership and technical assistance to other government entities, organizations, and individuals when prospective land-use and groundwater management activities in those entities' purview will, in the District's assessment, significantly affect the quantity or quality of groundwater in the Aquifer. The District will respond actively and appropriately to legislative initiatives or projects that affect Aquifer characteristics, provided such actions are consistent with established District rules, ongoing initiatives, or existing agreements.	●	PS 1-6, PS 4-3	

6.3 Monitoring Activities

All of the District operations are based on the philosophy that, "You can't manage what you don't measure." The HCP program will be no different, and the District will routinely and regularly monitor a suite of parameters that delineate its progress and outcomes, and the continuing implementation of the adaptive management process (Section 6.4, District HCP Adaptive Management Process) to improve performance. These monitoring activities, many of which are already being done, address Aquifer characteristics, Covered Species status, and overall conservation program management and performance. The monitoring program to be used by the District is described in detail in the following subsections. In addition, the monitoring data will be reported to and assessed annually by the Board and by the HCP Management Advisory Committee (MAC) as part of the HCP compliance monitoring and reporting initiatives, as described below.

6.3.1 General Groundwater Management Actions

Aquifer management will focus on an array of conservation measures directly or indirectly affecting the withdrawal of water from wells in the Aquifer to maintain springflow in Barton Springs, as outlined in Section 6.2.1, Direct HCP Measures.

A validation monitoring program will be developed and implemented to measure future success of Aquifer-management activities, and to modify management actions on the basis of new information. This program will be conducted in collaboration with the COA under an ILA for each entity's HCP monitoring reports. The following data and information will be compiled by the District for this HCP each year and reviewed annually by the Board and the HCP MAC:

- Survey data on the Covered Species, collected bimonthly by the COA; water quality and habitat data collected by the District, COA, and/or other entities; and trends in water quality and habitat data, to consider the need to re-evaluate biological risk during low-flow conditions;

- Results of any numerical or analytical modeling of the Aquifer and salamander population dynamics on which the HCP is based that are reported each year, to assess the current worth and continuing validity of such tools and concepts; and

- Available data on the total annual discharge of Barton Springs, its temporal and spatial variations, and the aggregate withdrawals from wells in the Aquifer, to inform periodic water-balance (inflows to and outflows from the Aquifer) modeling.

In the first year of the ITP term, the District will collaborate with the COA to formulate a methodology for monitoring and evaluating take associated with the District's Covered Activities. This methodology will use existing springflow gaging, water chemistry monitoring, and salamander censuses, supplemented as needed by new data collection and analyses. Following review by the MAC and subsequent review and approval by the Board, the monitoring methodology will be submitted to the U.S. Fish & Wildlife Service (Service) for its concurrence before or along with the Annual Report issued after the first full year of operating under the ITP. The activities required by the collaborative take monitoring methodology will be an element in the prospective ILA between the COA and the District.

6.3.2 General Performance Metrics and Reporting

A process will be developed to evaluate performance of the District HCP measures and groundwater management strategies, including:

- Frequency or necessity of Stage II Alarm-, Stage III Critical-, and Stage IV Exceptional-Drought Measures;
- Levels of the Aquifer as indicated by springflow and water levels in designated (indicator) wells;
- Daily mean discharge from Barton Springs;
- Through coordination with COA staff, reporting of:
  - current and historical biological data to evaluate responses to groundwater management actions during any low-flow conditions;
  - availability of suitable habitat during various low-flow conditions;
  - relative salamander abundance and population characteristics based on observations during low-flow and other conditions;
  - water-chemistry characteristics related to flow through the spring orifices during normal and low-flow conditions; and
- Educational outreach program summaries, including quantity, quality, and timeliness of information disseminated to the general public and stakeholders about water use, demand management, and aquifer conditions.

These performance metrics, which generally compose the HCP effectiveness monitoring program, will be compiled, analyzed, and presented in a report to the HCP MAC and to the Service on or before the third-year anniversary of ITP issuance and every 5 years or less thereafter, for the duration of the ITP.

6.3.3 Implementation Monitoring

The District will ensure that all management objectives are realized to meet requirements specified in the Performance Metrics through execution of the MP and the reporting procedure outlined in Section 6.5.1.1, Administration and Reporting.

6.3.4 Effectiveness Monitoring

The District determines actual groundwater withdrawals through required monthly water-use reports from all nonexempt users. The Board reviews reported metered data on a periodic basis during declared drought, and confirms/clarifies withdrawal trends in the District, both overall and by permittee. Setting of the meters and their calibration are required to be in compliance with standards and rules of the District. The results of comparisons of metered groundwater withdrawals relative to then-authorized amounts, including both aggregate and individual permittee performance, are the fundamental tool used to monitor effectiveness of the District HCP and MP with respect to withdrawals from the Aquifer.

The District will, in coordination with the COA and under the auspices of the ILA that both entities intend to inform their respective HCPs, obtain and report biological survey data and analyses being evaluated on a continuing basis by the COA. The District believes the COA's biological data collection activities under its Barton Springs Pool HCP are sufficient for the purposes and needs of the District HCP, with no benefit in duplicative efforts nor need to augment the frequency or extent of current COA data collection. As specific data needs and gaps are identified that may require a focused research effort (corresponding with adaptive management measures specified in Section 6.2, Minimization and Mitigation Measures, or in the Adaptive Management Plan [AMP]), the District will consult with the Service and the COA and commit resources for such research, to the extent that additional funds and in-kind labor are available (see Section 8, District HCP Funding Assurances, for details on funding).

6.4 District HCP Adaptive Management Process

The District reasonably believes that the initial HCP conservation measures to be funded by the District for its HCP will be effective in conserving habitats and the Covered Species for the term of the ITP. However, monitoring the implementation of these measures, including the proposed Research Measures, will continue to provide feedback on the efficacy of those measures and also may continue to produce data and information that can be used to identify and evaluate improvements and other management options. In addition, over time Changed and Unforeseen Circumstances (Section 7) may affect the status of habitats and the condition of the species within the Barton Springs ecosystems; and the uncertainties identified in Section 7.2.1, Considering Specific Uncertainties, may be resolved or clarified.

Historically, the District has used an “incremental/rational planning” approach to adaptive management as an accepted resource management practice and as an integral part of rulemaking as its drought management planning has evolved (Section 4.1.2, Historical Perspective of Covered Activities). For the HCP, the District has evaluated the specific AMP protocols implemented by the U.S. Department of the Interior (DOI) in its Adaptive Management Implementation Policy (DOI, 2008) and stipulated for use in HCPs by the Service, an agency of the DOI. Passive adaptive management in a general sense has been a primary means by which the District evaluates and incorporates alternative management actions. This will continue under the HCP as the proposed measures are implemented, as monitoring data are collected, and as uncertainties in the natural systems are resolved. Over time, new management activities will be added under the direct measures for avoidance, minimization, and mitigation as they prove prudent, feasible, and warranted, using the DOI/Service AMP protocol if and when it is appropriate and the District’s own incremental/rational planning approach when it is not.

The DOI/Service AMP protocol is an active, structured process and a defined method for addressing uncertainty in natural systems when:

- One or more issues can be articulated as outcomes of management options,
- A relatively frequently *recurring* decision must be made (which allows for regular and controlled testing and therefore optimization of results),
- Various management approaches or strategies can be applied by an agency to the system to affect observable results on a planned, iterative basis,
- Uncertainty can be expressed in terms of testable hypotheses or models of management options, and
- Monitoring can be designed and implemented to reduce uncertainty and deliver timely conclusions that can affirm or be used to adjust resource management outcomes for the next iteration of testing.

Section 7.2.1, Considering Specific Uncertainties, identifies a number of uncertainties that may affect the HCP during the term of the ITP. The main management issues for the District HCP arising from these uncertainties are:

- What are the physical and hydrochemical responses of the Aquifer system during Extreme Drought conditions that are equivalent to a recurrence of the DOR, as those conditions have not occurred since the Covered Species were first identified?

- Does the current (2014) DFC of the Aquifer during Extreme Drought—that is, monthly mean springflow no less than 6.5 cfs—actually result in, as intended, water chemistry that allows the populations of the Covered Species to survive and to recover?

- Does the ability of the Covered Species to migrate into the subsurface environment between and around spring outlets provide a safe harbor when the surface environment is critically deficient in one or more of their life requirements?

- Does provision of alternative water supplies to existing users of the Aquifer translate confidently into actual reductions in withdrawals from the Aquifer during drought periods and into increased springflow?

These issues constitute the focal points and potential objectives for this HCP's adaptive approaches.

The Covered Activities in this HCP constitute a natural resource management program specifically designed to address the system variations (water levels and springflows) induced by natural drivers (drought, water-supply demand) that occur in a natural system (the Aquifer). There is a mandate for protection of the Covered Species, and the District has the institutional stability and legal authority to be a resource management agency. Such characteristics *per se* might otherwise suggest that this program could be a candidate for the defined adaptive management planning protocol that is described in the DOI Technical Guidance for Adaptive Planning (DOI, 2008); further, there are several "AMP success factors" present, including committed executive leadership, long-standing stakeholder involvement, and a perceived high value associated with new information for reducing uncertainty.

However, there are a number of other factors that, in aggregate, work against implementing the more active AMP protocol under the DOI guidance for this HCP:

- Despite best science and sound resource management practices, it is difficult in this instance to confidently gauge effects and responses of alternative management actions of various types without forcing changes in some variable; for example, allowing larger, shorter-term withdrawals under some specified condition that may put the Covered Species' populations at mortal risk.

- The District cannot control the existence and variable recurrence frequency of either the forcing functions (floods, droughts) or the Aquifer system responses to provide useful information on impact to the Covered Species, especially in the time periods of interest for an AMP.

- The District cannot control the variable magnitude of the forcing functions, except droughts and even then only within some fairly narrow limits that would yield useful interpretative information on management options.

- Monitoring of the response of the Covered Species to management actions is confounded by the small and not easily observable populations of the Covered Species and by the multiple environmental factors that affect that population, only one of which (groundwater withdrawals) is within the District's statutory purview.

- As discussed in Section 4.1.2, Historical Perspective of Covered Activities, as an outgrowth of recent State legislation, the District now has a statutory obligation to allow the maximum practicable level of groundwater withdrawals while administering a drought management program that is consistent with achieving the DFCs of the Aquifer; that is to say, the District cannot arbitrarily (from a groundwater owner's perspective) reduce the amount of otherwise authorized withdrawals as part of a hypothesis-testing program.

Therefore, the District has concluded that the primary direct HCP measures that are the proposed components of this management system (Section 6.2.1, Direct HCP Measures) are not amenable to the Service's active, structured AMP protocol implementation and that that AMP is inappropriate for use in the District's HCP. In lieu of using the active, structured processes of the AMP for these measures, the District will continue to evaluate its proposed HCP conservation measures using its currently implemented incremental/rational planning approach to help resolve the issues described above. For example, if pertinent new statutory authority is provided by the Texas Legislature to GCDs such that the District could differentiate levels of curtailment during Extreme Drought by groundwater use type (currently not legally possible), the District would consider and then could adjust its drought curtailment program to reduce withdrawals by certain types of permittees even more and thereby further minimize take of the Covered Species.

6.5 Implementation Roles of Plan Participants

The District is applying for a 20-year ITP to allow incidental take of Covered Species in the Barton Springs ecosystem. Responsibilities of the participant and cooperating entities are outlined below. The ITP generally will specify responsibilities of the permit holder, conservation and mitigation measures to be implemented, monitoring and research procedures, and any other permit conditions that may be required, and the District will ensure they are addressed during HCP implementation.

6.5.1 Barton Springs/Edwards Aquifer Conservation District

The District, or BSEACD, is the applicant for the ITP and is the only Participant, as the term is defined by the Service, in the District HCP. The District will be the ITP holder. The ITP will cover the District, as the groundwater management entity, and all groundwater producers in the District's jurisdiction that hold production permits from the District, as the authorized users of groundwater being managed by the District.

As the District issues and renews groundwater production permits, the permittees' water-use fees and other fees paid by the COA that are associated with use by the permittees will generate funding for the HCP. Typically and generally, this funding will support implementation of the HCP conservation program and the administration and reporting associated with the HCP by offsetting the direct and indirect cost of internal labor and other direct costs. The bulk of the funding commitment discussed in Section 8, District HCP Funding Assurances, will be used in this way. Beyond the internal support needs of the HCP, the District will distribute part of this revenue to other entities, if and as authorized by bilateral contractual agreements; or to pay for in-kind services of the District and for external goods and services provided by other entities.

The District will be responsible for implementing drought-stage management as well as comprehensive management of the aquifer, using its rules and statutory authorities, and for monitoring compliance and effectiveness.

The District will report no less frequently than annually to the Service on the status of Aquifer withdrawals, drought-stage management, results of monitoring programs, efficacy and issues associated with minimization and mitigation measures, and adaptive management needs and opportunities.

Details on each of these processes are presented in the following subsections.

6.5.1.1 Administration and Reporting

The District will provide to the Service an annual report on the progress of and plans for implementing the District HCP at the same time each year as specified by the Board. More specifically, this report will summarize information on the management and monitoring of the Aquifer including:

- Reported groundwater withdrawals from permitted wells;
- Reference well levels;
- Springflow at Barton Springs;
- Total Aquifer discharge, measured for permitted wells, estimated for exempt wells, gaged/measured for Barton Springs; and estimated for Cold & Deep Eddy Springs;
- Drought-stage management reductions;
- Estimated actual take, if any, for the annual reporting period, and total cumulative take for the ITP term;
- Adaptive management activities undertaken during the year or indicated as prudent by outcomes of the conservation program;
- Expenditures by the District on implementation activities; and
- Proposed activities for the next year.

In addition, the report will summarize any groundwater management actions undertaken by the District and any species-specific research reports compiled or completed by investigators in the reporting year that relate to the biological objectives identified for the Covered Species or improvements in the assessment of and appropriate responses to actual take. This annual report may also contain other, non-HCP information and may also be used to report the progress and plans of the District as a GCD to the Texas Commission on Environmental Quality (TCEQ), as required by District bylaws.

This annual report will be submitted simultaneously to the Service and to the HCP MAC, described in the subsection immediately following, for their respective review and comment by February 28th each year.

6.5.1.2 District HCP Management Advisory Committee

The District has established an HCP MAC to advise and assist the Board in the coordination of conservation activities affecting Covered Species at Barton Springs, and in monitoring and helping the Board improve the implementation of the District HCP for the District. This MAC is an additional measure to ensure continued improvement of the HCP and compliance with the ITP as well as to ensure the Board is aware of any stakeholder concerns regarding the execution of the HCP and revisions to the HCP. The primary purpose of the MAC is to review and comment to the District's Board of Directors on the District's HCP annual reports, in a manner of the MAC's choosing. At the Board's discretion, the MAC may also be requested to:

- Provide a forum for exchange of information relative to Covered Species,
- Provide advice on Covered Species management activities,
- Advise the District on priorities for conservation actions, and
- Provide input and recommendations, as warranted, on the development and implementation of actions through the adaptive management program.

The MAC was appointed by the District Board in early 2013 and includes independent, volunteer representatives with biological or natural-resource management responsibilities from designated interest groups. MAC composition focused on perspectives useful to the active management of the Aquifer and the habitat of Covered Species at Barton Springs. The interest groups that compose the MAC are:

Texas Parks and Wildlife Department (TPWD)
City of Austin Watershed Protection Department (COA WPD)
Environmental community
Technical/ecological research expertise
Salamander biologist/expert
Public water-supply permittee
Large private-sector permittee
Aquifer-using landowner
Private property conservation interests
River authority
County government
Interested private citizen/public at-large (2)
District technical staff

The Service was also requested to provide a non-voting representative to be liaison between the District, the Service, and the MAC.

This MAC is a standing advisory group to the Board for the HCP. The individuals serving as MAC members are reasonably expected to change from time to time over the 20-year term of the ITP. However, provided replacement members are appointed by the District Board from the same interest group, such changes are proposed to be considered administrative.

The MAC will convene in some manner appropriate to the purpose of each meeting and no less frequently than annually, and at such other times as requested by the Board. The MAC at its discretion may form subcommittees to address specific issues or topical areas pertinent to the HCP and the MAC's charge. It will receive and review the District's annual progress report and associated other documentation pertaining to the ITP. In a forum of its discretion each year, it will evaluate HCP progress and identify any concerns that a consensus of the MAC finds important to convey; and at its discretion, report its findings in a presentation directly to the District Board each year.

In addition, every 5 years the MAC will review the District-prepared report on the performance of the HCP measures, as described in Section 6.3, Monitoring Activities, and make recommendations for adjustments or improvements, as warranted, in a letter report to the District's Board.

6.5.1.3 Adaptive Management Process

The District may implement an adaptive management process as appropriate to address:

- Guiding long-term aquifer-management monitoring and research planning,
- Further defining critical attributes and linkages within and between physical components of the spring ecosystem,
- Promoting improved understanding of uncertainties and other key factors that drive changes in the spring ecosystem,
- Making qualitative and quantitative assessments of resource changes resulting from flow variation and impacts to the Covered Species,
- Providing information to stakeholders regarding the potential impacts and benefits of flow variation in the Barton Springs ecosystem.

Certain direct and indirect measures, especially research measures, as presented in Table 6-1, and the actions taken in response to Changed and Unforeseen Circumstances (Section 7), may identify needs for a specific adaptive management response. These needs will be characterized and future action recommended, if feasible, in the Annual Report. As appropriate, a future AMP project will conform to the DOI/Service technical guidance document, as discussed in Section 6.4, District Adaptive Management Process.

6.5.1.4 District Enforcement Program

The District has established an aggressive enforcement program under District Rule 3-8, Enforcement (Appendix K provides the entire District Board-approved Enforcement Plan). The District enforces all of its Rules, whether for permit violations (for example, overpumpage), well-construction violations, wasteful water use, or failure to make timely use reports and fee payments. Enforcement measures are, in typical order of their use: warning letters, assessment of fines and penalties through agreed enforcement orders, show-cause hearings, "red-tagging" of wells that limit or prohibit withdrawals from permitted wells, temporary suspension of permits, revocation of permits, and finally litigation in District court (which is rarely needed). Under District policy, enforcement priorities in any one drought stage focus first on the most egregious non-compliant users, those with the largest amounts of permitted pumpage and/or those with the largest percentage of monthly overpumpage.

Of particular note with respect to the District HCP are the enforcement measures and penalties that have been established during declared droughts. Each day that a violation occurs is a separate violation, and the penalties are cumulative. Every District permit contains both a User Conservation Plan (UCP) and a User Drought Contingency Plan (UDCP) as an agreed part of the permit, specifying both voluntary and mandatory actions that the permittee and end users, as warranted, will take under various drought stages. The UDCPs include drought-time curtailment charts that specify the allowed pumpage each month during various drought stages and emergency response periods of various durations. Penalties related to pumpage violations during Critical-Stage and Exceptional-Stage drought carry twice the dollar fines as those during Alarm-Stage Drought. These penalties have been determined to have considerable deterrent value and success in attaining compliance with District pumpage regulations. The daily penalties for violations related to failure to reduce pumpage during District-declared drought are shown in Table 6-2 below. Changes to the penalty structure and amounts that do not affect compliance and therefore take would be a proposed administrative change under the HCP and not require an HCP or ITP amendment.

Table 6-2a: Daily penalties for violations of District drought rules during Stage II-Alarm Drought, Rule 3-7.7.B(1).

	Overpumpage Level		
	Level A	**Level B**	**Level C**
Tier 1	$50–$100	$100–$200	$200–$400
Tier 2	$200–$400	$400–$800	$800–$1,600
Tier 3	$800–$1,600	$1,600–$3,200	$3,200–$5,000

Table 6-2b: Daily penalties for violations of District drought rules during Stage III-Critical and Stage IV-Exceptional Drought, Rule 3-7.7.B(2).

	Overpumpage Levels		
	Level A	**Level B**	**Level C**
Tier 1	$100–$200	$200–$400	$400–$800
Tier 2	$400–$800	$800–$1,600	$1,600–$3,200
Tier 3	$1,600–$3,200	$3,200–$6,400	$6,400–$10,000

Table 6-2c: Definition of tiers of permitted pumpage and levels of overpumpage during all drought stages.

Permitted Pumpage (gallons/year):		**% Pumpage Over Monthly Target:**	
Tier 1:	< 12,000,000	Level A:	< 25%
Tier 2:	≥ 12,000,000 and < 120,000,000	Level B:	> 25% and < 100%
Tier 3:	≥ 120,000,000	Level C:	> 100%

6.5.2 Cooperating Federal and State Agencies

6.5.2.1 U.S. Fish and Wildlife Service

The Service is the federal agency responsible for issuing the ITP and monitoring compliance with the ITP conditions. The Service, as the regulatory agency for the District ITP, will review and comment on the Annual Report and other HCP monitoring reports provided by the District.

6.5.2.2 Texas Parks and Wildlife Department

The Covered Species are also species listed by the TPWD as Species of Greatest Conservation Need (TPWD, 2012), and therefore the TPWD is a supporting governmental entity of this HCP. Involvement by the TPWD as well as other State governmental agencies and political subdivisions in the development of HCPs is guided by provisions of Subchapter B, § 83.011 through §83.020 of the Texas Statutes, Parks and Wildlife Code. These subsections lay out definitions of HCP; regional HCPs; land development standards; and plan participants, structure and function of advisory committees; and provide guidance for acquiring habitat preserves. TPWD is also providing a member of the proposed MAC to assist the District in the implementation of the District HCP. Other TPWD activities—including biological consultation, coordination, or participation in future adaptive management strategies—remain unspecified and will be consistent with TPWD authorities and needs during the implementation of the HCP.

6.5.3 City of Austin and Barton Springs Pool HCP

The COA is not an applicant in the District HCP. However, the COA, which is traditionally a collaborative partner with the District in many of its programs, is currently providing a substantial portion of the total funding for the District, including in part the conservation measures of the District HCP. In addition, the COA has a complementary HCP for operation and maintenance of Barton Springs Pool (City of Austin, 2013.) The District intends to take advantage of the opportunities that likely exist for beneficial interaction between the two related HCPs. Under the District HCP, the District and the COA propose to collaborate through an ILA and/or an MOU in the following areas, as one of the Indirect HCP Measures arising from the District's adaptive management process:

- Provision of data and evaluation reports, in preliminary and final formats, to the District so that mutual interests on the viability of the Covered Species and on aquifer/spring dynamics are being met;

- Collaboration and participation with the District in long-range planning, to provide COA water supplies and possibly other alternative sources to new and existing communities and businesses in the District HCP Planning Area in lieu of Aquifer water supply; and

- Collaboration and participation in a variety of investigations, mitigation measures, and adaptive management measures, as specified in Section.6.2.2, Other HCP Measures and Strategies, as well as continuing collaboration with the COA in dye tracing, springflow measurement, and the adjustment and validation of low-springflow rating curves (A rating curve here refers to the relation between springflow and the water level in a nearby Aquifer well).

While perhaps not included explicitly in the ILA provisions, the COA representative(s) on the MAC will be invaluable in conveying the results and conclusions of the COA's complementary investigations to other members of the MAC.

6.5.4 Other Entities

Other governmental entities, political subdivisions, universities, or private research groups may be involved cooperatively in conducting studies or other actions identified or included as District HCP measures. If they become an essential condition in maintaining ITP compliance, specific responsibilities of the parties would be identified in District HCP contracts or implementation agreements with the District. The current statutory and/or management responsibilities of certain entities could either directly or indirectly affect HCP implementation:

- U.S. Geological Survey—This agency administers programs to monitor Aquifer recharge, springflow, water levels, and water quality. The USGS currently operates monitoring wells and records and transmits to appropriate offices water level data at both sites that the District uses in its drought-trigger methodology for assessing drought stages.

- Texas Commission on Environmental Quality—This agency manages and protects water quality through regulation of point- and nonpoint source water pollution in the Edwards Aquifer and the contributing surface watershed. TCEQ also serves as the administrative regulatory authority for all GCDs in the state, including the District.

- Texas Water Development Board—This agency will review and approve the District's MP and provide additional support to the District on compliance with state laws pertaining to groundwater management, especially those related to specifying the Modeled Available Groundwater associated with DFCs.

- Other Groundwater Conservation Districts—The five other GCDs in GMA 10 are statutorily charged with establishing and reviewing the DFCs for the Aquifer at least every 5 years. A two-thirds super-majority is required to amend and approve (and re-adopt) the DFCs set by the GMA. In addition, GCDs in GMA 9, especially the Hays Trinity GCD and Blanco Pedernales GCD, authorize withdrawals from the Trinity Aquifer in the Contributing Zone of the Barton Springs segment of the Edwards Aquifer, which may affect the quantity and quality of contributions of base flow to the up-gradient creeks that recharge the Aquifer.

7.0 Changed and Unforeseen Circumstances

Regulations implementing Section 10 of the Endangered Species Act (Act) (50 CFR 17.22(b)(2)(iii)) require that a Habitat Conservation Plan (HCP) specify the procedures to be used for dealing with Changed and Unforeseen Circumstances that may arise during HCP implementation. In addition, the HCP Assurances ("No Surprises") Rule (50 CFR 17.2, 17.22(b)(5) and (6); 63 FR 8859) defines "Unforeseen Circumstances" and "Changed Circumstances," and describes the obligations of the permittees and the U.S. Fish & Wildlife Service (Service) under such circumstances.

7.1 Responding to Changed Circumstances and Unforeseen Circumstances

The District has made a concerted effort to anticipate the minimization and mitigation measures (conservation measures) and monitoring that are necessary to conserve the Covered Species and preserve the habitats that support the species and that are within its statutory authorities. To that end, the District has relied upon the best scientific and experience-based information available in preparing this HCP. The District also sponsored and contracted for original research and for relevant new data to be collected as a part of the District HCP development process to provide new information, to complement existing knowledge, and to manage groundwater withdrawals and springflow for the benefit of the Covered Species. In addition, the flexible provisions regarding the expenditure of funds authorized by the District Board for specific mitigation measures, including the indirect measures described in Section 6.2.2, Other HCP Measures and Strategies, and specifically the Adaptive Management Plan (AMP) measures in Section 6.4, District HCP Adaptive Management Process, are designed to address future needs and emergency situations. Thus, the District HCP intends to minimize the potential for adverse Changed or Unforeseen Circumstances on the Covered Species and its habitat.

However, these provisions notwithstanding, Changed or Unforeseen Circumstances may occur during the course of a long-term permit program like the ITP. So provisions for addressing such conditions are part of each HCP. In this context, only those circumstances that the Covered Activities may affect or may be affected by are relevant to the District HCP.

The District HCP's AMP is one mechanism that the District will use to anticipate optional responses and evaluate outcomes to certain Changed Circumstances and Unforeseen Circumstances. Additional information on how the District will respond to these circumstances follows.

7.1.1 Resolving Adverse Changes

A principal aspect of the HCP is a commitment by the District that (a) should certain Changed or Unforeseen Circumstances result in or threaten a substantial adverse change in the population of the Covered Species or the overall quality of any habitat of the species, and (b) should it be determined that the Covered Activities contribute to either the cause or the resolution of the adverse change, as determined pursuant to the procedure outlined herein, the District and the

Service shall cooperate to resolve the adverse impacts in accordance with the definitions and guidance provided by the Services' HCP Assurances ("No Surprises") Rule:

- **For Changed Circumstances—**If additional conservation and mitigation measures for the Covered Activities are deemed necessary to respond to changes in circumstances provided for in the District HCP, the District as the ITP permittee will be expected to implement the responsive measures specified in the HCP, but only those measures and no others; and

- **For Unforeseen Circumstances**—The Service statutorily may not require the commitment of additional land or water resources or financial compensation—including additional restrictions on the use of land, water, or other natural resources—even upon a finding of Unforeseen Circumstances, unless the permittee consents. Upon a finding of Unforeseen Circumstances, the Service may have only limited ability to require additional measures or modifications within the conserved habitat areas that are inconsistent with the District's approved Management Plan (MP) that authorizes its groundwater management program and the District HCP. Additional required conservation and mitigation measures will not involve the commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources.

Consultation between the Service and the District also may indicate that the adverse changes may be most appropriately addressed through an amendment of the ITP and HCP.

7.1.2 Method for Developing Criteria for Changed Versus Unforeseen Circumstances

The District has determined that changes in several specific circumstances are reasonably foreseeable and therefore should not be considered unlikely to occur during the course of the HCP and the term of the ITP. The District has determined which of these are related to Covered Activities of the District HCP and are therefore actual Changed Circumstances under the Act. These circumstances are discussed in Section 7.2.2, Responding to Changed Circumstances. Not reasonably foreseeable and Unforeseen Circumstances (Section 7.3, Unforeseen Circumstances) could also affect the District HCP, as provided for under the Service's HCP rules and guidelines. In addition, several factors that influence the ecosystem are either not known or only poorly known, as indicated in Section 7.2.1, Considering Specific Uncertainties. The likelihood of those factors affecting HCP conservation measures is uncertain. They could result in either Changed or Unforeseen Circumstances. The District will consult with the Service and seek a determination by the Service whether a particular event or change in a relevant circumstance or factor constitutes a Changed or Unforeseen Circumstance under the District HCP, generally on the basis of the likelihood of the change or event reasonably being anticipated to occur during an average 20-year period (the proposed term of the District HCP) and reasonably being related to the Covered Activities. The respective responsibilities of the District and the Service in determining Unforeseen (and therefore not "Changed") Circumstances are discussed in Section 7.3.1, Responding to Unforeseen Circumstances.

7.2 Changed Circumstances and Uncertainties

The Service defines the term "Changed Circumstances" to mean "changes in circumstances affecting a species or geographic area covered by a conservation plan…that can reasonably be anticipated by plan…developers and the Service, and that can be planned for" (40 CFR §17.3). Examples provided include listing of new species in the plan area (Section 7.2.2.1, Listing of New Species Not Covered by HCP) or some extreme event in areas prone to such events, most notably drought severity equivalent to the DOR.

Substantial uncertainties exist in the various bases for developing conservation measures for the Covered Activities, and to the extent these uncertainties show themselves in unplanned ways that affect the ITP during the term of the ITP, they may produce Changed Circumstances. These uncertainties are addressed in the next section.

7.2.1 Considering Specific Uncertainties

A number of issues and uncertainties could create Changed Circumstances, including the uncertain existence and magnitudes of various factors that could affect the ITP, HCP effectiveness, or that are not otherwise quantifiably taken into account in the District HCP. Under the District HCP, District staff will continue to monitor and to develop new information that will address and resolve known issues, clarify others, reduce uncertainties, and mitigate impacts associated with the Covered Activities; and consult with the Service as warranted to evaluate the need for amendments to the HCP and ITP. The following subsection identifies the more important issues and uncertainties and their possible effects and impacts, without attempting to characterize or evaluate them in detail.

7.2.1.1 Global Climate Change: Effects and Probabilities

Probably the largest uncertainty that may substantively affect the long-run effectiveness of the District HCP measures relates to "climate change" in the larger sense. The uncertainty isn't related to whether climate change is now occurring. As described in EARIP (2012),

> The U.S. Climate Change Science Program (CCSP) has concluded that the global climate is changing. Effects of this change on the existing environment have been evaluated in a 2008 U.S. national scientific assessment (National Science and Technology Council, 2008) which integrates, evaluates, and interprets the findings of the CCSP and draws from and synthesizes findings from previous assessments of the science, including reports and products by the Intergovernmental Panel on Climate Change (IPCC).
>
> The conclusions in the National Science and Technology Council assessment build on the vast body of observations, modeling, decision support, and other types of activities conducted under the auspices of CCSP and from previous assessments of the science, including reports and products by the IPCC, CCSP, and others. This assessment and the underlying assessments have been subjected to and improved through rigorous peer reviews. According to CCSP's Synthesis and Assessment Product (SAP) 4.3 (Backlund et al., 2008), it is very likely that temperature increases, increasing carbon

> dioxide levels, and altered patterns of precipitation are already affecting U.S. water resources, agriculture, land resources, biodiversity, and human health, among other things. SAP 4.3 also concluded that it is very likely that climate change will continue to have significant effects on these resources over the next few decades and beyond.

The IPCC has also determined that warming of the global climate is unequivocal, and emissions of greenhouse gases emitted by humans are largely responsible for the warming over the past 100 years (IPCC, 2007b, 2013). In the future, the net global effect of the warming, even if no additional greenhouse gases are emitted, will be increased precipitation, though with variable spatial distribution and intensity. Extreme weather events, such as heat waves, flooding, and drought, will continue to increase in frequency and intensity, as well as adverse impact (IPCC, 2007b, 2013; USGCRP, 2014).

The uncertainties arise as to what that means for the HCP region generally and for the Covered Species particularly. The Summary for Policy Makers prepared by the IPCC (2007b, reinforced in 2013) suggests there is high confidence (8 out of 10 chances) that drought and flooding will be both more severe and frequent, and those conditions will have mostly negative consequences for ecosystem structure, function, inter-species interactions, and therefore biodiversity. It includes more detailed predictions of long-term changes in precipitation patterns, at both global and regional levels (IPCC, 2007a). The impacts that have been predicted for Central Texas, according to one model (A1B), would result in a 10–20% reduction in precipitation during the winter months by 2090–99, relative to 1980–99 conditions; but no clear trend in the direction of change for precipitation during the summer months by 2090–99. These slight and variable differences are reflected in Figure 7-1 from modeling of these data by the Nature Conservancy (Maurer et al., 2007), which shows the sensitivity of precipitation projections by this model to emission scenarios, especially in Central Texas.

Joseph Alcamo, a lead author of many IPCC publications on climate change and water resources, has developed and applied another global water model to analyze the impacts of climate change and socio-economic driving forces on future global water stress, derived from the A2 and B2 scenarios of the IPCC (Alcamo et al., 2007). The investigators define “water stress” as the intensity of pressure put on water resources and aquatic ecosystems by external drivers of change. The principal cause of *increasing* water stress, where it occurs, is increasing water withdrawals. Alcamo and other investigators show increases in water stress for the Central Texas region of between 50% and 100% by the 2050s, under two different IPCC scenarios (A2 and B2). This work and other more local, as well as large-scale, scenarios indicate that significant additional challenges and competition for water, and correspondingly less water availability for wildlife and other instream functions, must be anticipated and confronted.

The uncertainty in climate change effects on local precipitation has been underscored by Nielson-Gammon (2011), who noted that observed variations in precipitation over the past century in Texas are larger than most future climate projections of precipitation changes by mid-century.

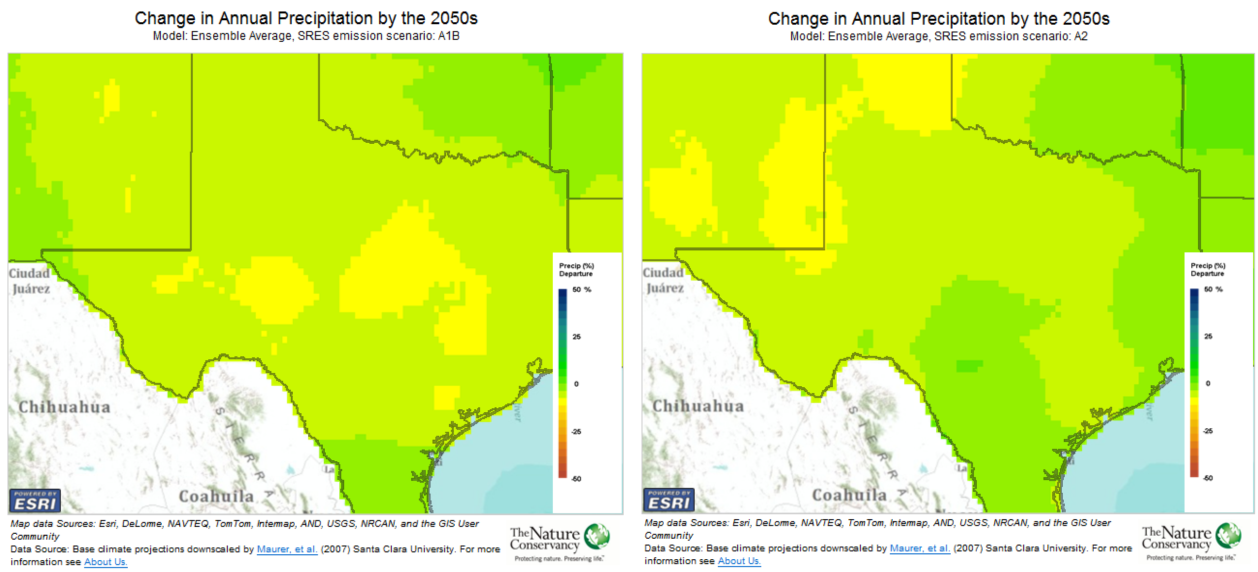


Figure 7-1: Change in annual precipitation projected over Texas by mid-century. Changes based on the median of models used in the IPCC Fourth Assessment and the A1B emissions scenario (medium) on the left and the A2 (high) on the right. Areas in darker shades of green are projected by half the models to increase and areas in yellow and lighter shades of green are projected by half the models to decrease (Maurer et al., 2007).

Nevertheless, governmental agencies and other organizations that participate in water-resource planning are either currently planning for the potential changes due to climate change, or they intend to incorporate that into future planning. Hirsch (2008) recommended the following approach to water-resource managers: (1) collect more data, (2) consider paleoclimate records, (3) keep an eye on climate science and change, and (4) don't lose sight of other stresses (for example, population and demand, urbanization, return flows, etc.).

7.2.1.2 Effects of Climate Change on Regional Groundwater Systems and Aquifer

A growing consensus among climatologists suggests that the next 50 years is likely to be warmer and drier in the HCP Planning Area than the previous 50 years (Seager 2007a, 2007c), especially if anthropogenic climate changes continue to accelerate, but also even if atmospheric carbon dioxide concentrations stay at current levels (Seager et al., 2007a):

> According to research compiled by the IPCC, from 1970 to 2004, much of the region that includes Central Texas has encountered a warming trend on the order of 0.2-1.0°C (IPCC, 2007a). The IPCC findings include new and stronger evidence of observed impacts of climate change on unique and vulnerable systems, with increasing levels of adverse impacts as temperatures increase further. An increasing risk of species extinction is projected. Confidence has increased that a 1 to 2°C increase in global mean temperature above 1990 levels (about 1.5 to 2.5°C above pre-industrial levels) poses significant risks to many unique and threatened systems

including many biodiversity hotspots.

While Global Circulation Models (GCMs) are a key tool for predicting and analyzing climate change, and regional predictions for Texas are reported (Seager, 2007), GCMs are not yet useful enough for predicting and assessing impacts in regional areas such as Texas. For example, rainfall is a key variable to assess environmental impacts (Leung, 2008). However, rainfall predictions from GCMs have the lowest confidence of simulated results and a lot of variability. Most GCM models suggest a "general drying" for Texas (Washington, 2008), but this is not consistent with regional rainfall and stream flow trends in Texas (Hunt et al., 2012b; Nielson-Gammon, 2008; Singh, 2008; Leung, 2008). In the last 30 years, Texas has been warming faster than the global average, has been unusually wet, and has experienced extreme events that likely will continue to happen in the future (Nielson-Gammon, 2008; North, 2008).

Texas will get hotter and climate change will exacerbate stresses already imposed upon water resources (Hayhoe, 2008). Climate in Texas continues to change, although impacts from those changes have not been observed as they have in the U.S. Southwest such as Arizona (Woodhouse, 2008). Generally, it is expected that rapidly responding aquifers such as the Edwards Aquifer will be more sensitive to changes in climate (Mace, 2008). However, no trends have been observed in recharge since the 1930s for the San Antonio segment of the Edwards Aquifer (Loaiciga, 2008). A study of hydrologic and hydrogeologic responses by Hunt et al., (2012b) in Central Texas concluded that, while there has been an overall increase in the amount of water in water budgets of various stream systems, the base flows of streams and springflows have slightly decreased over the past several decades since the DOR, likely owing to increased use of groundwater resources (Hunt et al., 2012b). This is particularly relevant to poorly controlled withdrawals from the Trinity Aquifer up-gradient from the ITP Area, which tend to result in lower base flows and flows of shorter duration in the creeks that contribute recharge to the Aquifer. But a study of global warming impacts on the San Antonio segment of the Edwards Aquifer by Chen et al. (2001) predicts that annual temperatures will rise (~3°F) and annual rainfall will decrease (~4 in) by 2030 resulting in a 20% decrease in recharge during droughts. However, these effects and their impacts are uncertain. Increasing demand due to population growth and rising temperatures will be the dominant factors impacting springs and water availability (Mace, 2008; Loáiciga, 2008). It seems clear that climate change will likely exacerbate these impacts, and vice versa.

As summarized in the EARIP (2012),

> "Climate change could impact groundwater resources by affecting recharge, pumping, natural discharge, and saline intrusion (Mace and Wade 2008). They suggest that climate change will more adversely affect karstic aquifers (like the Edwards Aquifer) that recharge locally from streams and rivers in comparison to aquifers where effective recharge is increased through pumping and the capture of intermediate and local groundwater flow paths. A warmer, dryer climate will increase demand for water to support agriculture, municipal, and industrial use. This will result in greater demand for both surface and groundwater. Decreases in surface-water supply due to climate change may also increase demand for groundwater use (Kundzewicz et al., 2007; Mace and Wade 2008). Natural aquifer discharge to springs and seeps is affected by recharge to the aquifer, discharge by pumping, and changes in groundwater

gradients as affected by plants, including phreatophytic species that demand higher amounts of water.

Mace and Wade (2008) and Loáiciga et al., (1996) suggest that the Edwards Aquifer is probably Texas's most vulnerable aquifer and groundwater resource with respect to climate change and variability and if there is a long-term drying of the climate in south-central Texas, area groundwater users can expect to be under more frequent drought restrictions.

Loáiciga et al., (2000) studied the climate change impacts on the Edwards Aquifer. Climate change scenarios were created from scaling factors derived from several general circulation models to assess the likely impacts of aquifer pumping on the water resources of the Edwards Aquifer. Aquifer simulations using GWSIM IV indicate that, given the predicted growth and water demand in the Edwards Aquifer region, the aquifer's ground water resources appear threatened under $2{\times}CO_2$ climate scenarios. Their simulations indicate that $2{\times}CO_2$ climatic conditions could exacerbate negative impacts and water shortages in the Edwards Aquifer region even if pumping does not increase above its present average level. The historical evidence and the results of this research indicate that without proper consideration to variations in aquifer recharge and sound pumping strategies, the water resources of the Edwards Aquifer could be severely impacted under a warmer climate."

It is possible that progressive increases in the ambient atmospheric temperature in Central Texas would lead to seasonal or year-round increases in the temperature of springflow at Barton Springs, possibly causing increased stress and vulnerability to disease for the salamander species there and possible reductions in DO saturation levels. Such temperature increases could be moderated to some unquantifiable extent by the long residence time of groundwater flowing from the Aquifer, especially during severe drought. It is also possible that any reduction in long-term average precipitation in Central Texas during winter could result in reduced storage in the Aquifer at the onset of spring and summer when water losses through natural processes and human activity increase. Such a condition could also exacerbate the reduction in summer springflow during droughts.

Although the State of Texas mandates use of the DOR for water-planning purposes, the DOR may not represent the worst-case condition that actually could occur in the ITP permit period (Cleaveland, 2006; Nielsen-Gammon, 2008; Woodhouse, 2008; see also Section 7.2.1.3, Ecological Significance of Paleoclimate Indications). Put another way, it is possible that the DOR could occur with higher frequency than history indicates. Under such circumstances, the sustainable yield of the Aquifer could be somewhat less than that indicated by modeling, and the lowest expected flows at Barton Springs could be lower, other factors being equal. On the other hand, the DOR has been estimated to have a recurrence interval about five times longer than the 20-year duration of the District HCP, as described in Section 4.2, Requested Permit Duration. These factors suggest that a recurrence of a drought causing Barton Springs flow to diminish to a level lower than has ever been recorded during the course of the ITP permit period is not likely.

Nevertheless, taken together these are trends for which additional attention and concern are warranted. There is a finite, although indeterminate, likelihood that an extreme record event would occur during the term of the ITP, and that the likelihood, although probably small, will increase under recent climatic trends to some indeterminate degree.

7.2.1.3 Ecological Significance of Paleoclimatic Indications

Tree-ring studies and stable isotopic evidence suggest that the part of the North American continent containing the study area has experienced much more severe (especially longer) droughts than the DOR during medieval times and even in prerecorded history (for example, Cleaveland et al., 2006; Seager et al., 2007b, 2007c). It is not known whether or how many times Barton Springs has stopped flowing over the course of several millennia. Yet the salamanders at Barton Springs have somehow survived. The District HCP is based on a premise that extremely low flow or no flow at the Barton Springs outlets could jeopardize the continued existence of the species; but whether that premise is true is unknown. The size and distribution of the Covered Species populations before the historic and prehistoric droughts are unknown, so it is not known if the populations are particularly persistent or are the last surviving remnants of much larger populations. Clearly the additional stresses contributed by cultural factors in the last century (for example, increased impervious cover and urban storm runoff) distinguish current and future responses from those of historic or prehistoric periods.

7.2.1.4 Lack of Water Chemistry, Water Quality, and Flow Data to Calibrate Models During Extreme Low Springflow Conditions

Modeling to predict springflow conditions as described in Section 3.2.2.1.2, Sources and Implications of Variation in Springflow at Barton Springs, like any modeling exercise, yield outcomes of predicted springflow that are not absolute. Rather, they are theoretical, predicted estimates affected by the limitations and accuracy of the model, quality of input data, and major assumptions. Therefore, analyses of predicted springflow in the HCP are limited to evaluation and comparison of alternative groundwater management strategies in a broad sense, not in a precise replication of a future scenario that is indeterminate.

The lowest recorded flow at Barton Springs is just under 10 cfs, which occurred during a period when little groundwater was being withdrawn from the Aquifer. Thus, no data are available to verify the relationship between predicted or modeled flow and water chemistry for flows less than 10 cfs. In fact, almost all information about the relationship between flow and water chemistry comes from flows that are no less than about 14 cfs. Accordingly, extrapolation of trends in flow, chemical components, and their relationships to flows less than 14 cfs is problematic. It is not known, for example, whether DO concentration continues to decrease as flow decreases or whether it “plateaus” at some small sub-saturated concentration. Water temperature, even though it varies over a relatively small range in the Aquifer, may affect DO concentration of springflow independent of springflow and water levels, as it relates to DO saturation (Mahler and Bourgeais, 2013). These same investigators note that critically low DO concentration can be caused by recharge from stormflow, especially during hot months. It is also not known whether and at what rate flow continues to decrease under prolonged Extreme Drought, or plateaus as a result of induced recharge of water that would remain in the larger and topographically higher San Antonio segment under more normal conditions. A statistical analysis of correlations between DO concentration and springflow between 1993 and 2011 by the COA may indicate a minimum DO concentration under ambient conditions that could be as high as 3.5 mg/L or as low as 0 mg/L (City of Austin, 2013). Although the COA has reasonably inferred a worst-case scenario, there currently is no unequivocal basis for reliably projecting the DO concentration at extremely low flow.

7.2.1.5 Cumulative Negative Effect of Pollutants in Groundwater Discharges on Salamanders

In development of the District HCP, studies funded by the District have focused on the relationship of DO concentration and specific conductance with toxicity and other adverse effects on the Covered Species. Of these parameters, DO concentration and springflow are believed to be controlling. However, the Service recently has suggested that specific conductance, indicative of the relative salinity of discharging groundwater, may also be important, especially to eggs and larvae (Service, 2013b); however, it is not known if the relatively small increases in salinity at low flows produce adverse effects. Springflow is presumably correlated with flow velocity in the habitat zones near the spring outlets, which in turn may be correlated with oxygen exchange potential across salamander gills (which is potentially important during periods of depressed DO concentration). Changes in DO concentration and salinity (and water temperature) are variations of the natural system unrelated to pollutants; but pollutants may produce adverse effects either on their own or in combination with changes in natural water chemistry.

Little information exists in the biological literature on impacts of other chemical constituents and physical conditions to the Covered Species. But nonpoint-source pollution in the Contributing and Recharge Zones of the Aquifer is already increasing the amount of anthropogenic pollutants like pesticides, domestic wastewater from decentralized and centralized treatment facilities, fertilizers and other nutrient sources, other oxygen-demanding constituents such as pet waste, suspended sediment, and some heavy metals in springflow (Mahler et al., 2011). Concentrations of those pollutants are likely to increase with time along with development, as additional volumes of treated domestic wastewater (sewage) and its oxygen-demanding waste loads are discharged directly and indirectly to streams that recharge the Aquifer. However, Mahler and Bourgeais (2013) suggests that there has been more recently a trend toward increasing DO concentration overall in the Aquifer, indicative of the complex controls on this parameter.

There has been no attempt in this HCP or in any other investigation to assess the impacts of different concentrations and mixes of water quality pollutants or their possible adverse impacts on the Covered Species, primarily owing to the vulnerability of the Covered Species. Because management of land use and associated development that generates pollutant loads are beyond the authority of the District and the scope of its programs, land use and associated development are therefore not proposed for management or research under the District HCP.

7.2.1.6 Response of Salamanders to Variations in Habitat Condition

By necessity, status of the Covered Species' populations is based on counts of observable individuals at the spring outlets and in spring runs. Low counts clearly are associated with stress-related impacts, including population declines (City of Austin, 2013). As noted in Section 5.1.2.1, [Distribution of] Barton Springs Salamander, it has been suggested by experts that salamanders appear to be able to migrate locally to areas of less stress in the Aquifer and in spring runs during certain periods, to an unknown extent. It seems reasonable that migration into the Aquifer and even to and from Main Springs is partly responsible for the observed rapid increase of the salamander population at Upper Barton Spring when that outlet starts flowing again after many months of no flow and no observable salamanders during the earliest stages of drought. On the other hand, during severe, prolonged drought conditions, the populations of both Covered Species at Old Mill Spring outlet decrease substantially to no or just a few individuals after extremely low flow at the outlet. Those very low observable numbers persist for months to years, even with re-establishment of some springflow.

The difference in behavior of these two populations and their ability to accommodate drought may be related to known differences in hydrogeologic conditions at the outlets. Such differences may be associated with the amount of subsurface migration that is possible. For the subterranean Austin blind salamander especially, low observable numbers during prolonged and/or severe drought may not be an indicator of mortality, although some population decrease during such periods of DO stress is reasonably expected. But the areal extent and proportional amount of such migration and their differences for either species, while inferred to occur, are largely unknown. These factors confound the quantitative interpretation of salamander reactions to stress and population impacts. These uncertainties probably reduce the reliability of stress and quantitative take estimates determined on the basis of counts. However, no other deterministic approach currently exists.

Other, more hydrologic uncertainties may relate to migration. Most natural discharge from the Aquifer occurs at Barton Springs. However, smaller springs have been noted that flow directly into Barton Creek, upstream from Upper Barton Spring and also into the Colorado River. The springs upstream from Upper Barton Spring only discharge under moderate-to-high flow conditions. Some small springs (for example, Cold Springs) are visible on the south shore of Lady Bird Lake at the water level of the lake. Other discharges into the riverbed but below the lake level are also possible, but they are difficult to discern either by direct observation or by monitoring temperature differences in the lake. The elevation of the lowest point in the Colorado River near the confluence with Barton Creek is about 412 ft msl. The elevation of the main discharge point at Main Springs is about 420 ft msl. Thus there is the potential for Aquifer discharge into the Colorado River owing to the elevation difference between the spring outlets and the base level of the river (TWDB, 1999). Although the presence of small springs below the lake level is unproven and would likely be only a very small component of the water balance for the aquifer as a whole, the conceptual model of the aquifer suggests that there are numerous small pathways for flow along faults, fractures, and bedding planes (surfaces that separate successive rock units or layers). Geologic mapping in the vicinity of Barton Springs shows that there are about six major faults that extend to the Colorado River between the downstream end of Barton Creek (confluence with the Colorado River) and Cold Springs. Fractures are common at outcrops of various Edwards Aquifer rock units. It is likely that small discharges occur where these faults, fractures, and bedding planes intersect the riverbed. Such discharges into the Colorado River may occur even with no flow at the major spring outlets. They may offer alternative groundwater flow paths and therefore possible flow environments with sufficiently high water velocities to support the salamander ecosystem. However, this is hydrogeologically informed conjecture at this point, as no studies have been done to address this uncertainty in subsurface flow environments and suitability and use as habitat of the Covered Species.

In addition, the conceptual model used by the District for the take estimate is that the spring outlets are hybrid springs, where water from both confined and unconfined parts of the Aquifer discharge. The relative proportion of flow from each of those parts of the Aquifer varies with time and differs among outlets. The unconfined parts of the Aquifer provide access for salamanders from the outlets to conduits and fissures at the water table (which is in contact with the atmosphere and provides a source of re-aeration within the Aquifer) and likely characterize the subterranean-only habitat of the Austin blind salamander. However, this is simply hydrogeologically informed conjecture at this point, as no studies have been performed to address this uncertainty in subsurface flow environments and suitability and use as habitat of the Covered Species.

7.2.1.7 Recent Texas Court Decisions and Aftermath

In a series of decisions, culminating in the *EAA v. Day and McDaniel* opinion in 2012, the Texas Supreme Court has now clarified that "groundwater in place" below the surface of the land is real property owned by the owner of the surface estate. It follows from the Court's decision that as real property, it is severable from the land and may be sold separately, although no specific amount of owned groundwater can be inferred *a priori*. Further, the Court has determined that, even though its withdrawal is subject to reasonable and equitable regulation by a GCD, a GCD's regulation that arguably produces an inequitable or unfair economic burden on a landowner with investment-backed expectations may outweigh the public interest in managing groundwater and is potentially regulatory "taking," subject to compensation.

Moreover, a recent appellate court ruling, in *EAA v. Bragg*, suggests that even rational, well-considered groundwater regulation may in fact be a taking for which the regulating GCD is financially liable. The assessment of compensable takings will be determined by future legislative action and judicial opinions, including likely appeals to the Texas Supreme Court.

Although the actual implications of these decisions for the District's operations are almost certainly to be elaborated further during the term of this HCP and ITP, it represents a new factor in the authority with which the District, or any GCD, may be able to limit groundwater withdrawals without putting its financial resources at risk. If it is ultimately decided that the District can be held financially liable for regulatory takings, it is not clear whether such a fundamental change in the District's regulatory capability is a Changed Circumstance or an Unforeseen Circumstance for its HCP or, alternatively, a basis for suspension or termination of the ITP by the Service. Ultimately the Service will be expected to make the determination of what sort of HCP circumstance exists for that eventuality.

7.2.2 Responding to Changed Circumstances

Although the District believes that the initial measures to be funded by the District HCP will be effective in conserving habitats and the Covered Species, it is anticipated that conditions within the aquifer, the status of habitats, and the overall condition of the species over time will change. In addition, it is likely that additional and different conservation measures, not contained in the District HCP, will be suggested and be proven to be effective during the term of the District HCP. Finally, measures currently funded by the District HCP may prove to be ineffective to conserve either the species or the habitats in which they dwell. These situations potentially constitute Changed or Unforeseen Circumstances. Therefore, the District is proposing to monitor and gauge the effectiveness of existing conservation measures on an ongoing basis; to evaluate alternatives in accordance with the monitoring reporting in Section 6.3.2 (General Performance Metrics and Reporting) and the adaptive management processes in Section 6.4 (District Adaptive Management Process); and to propose modifications, additions, or alternative conservation measures that could be implemented or supported by the District within its regulatory purview, including dealing with different circumstances as described below.

Events or situations likely to occur or that could be reasonably anticipated during an average 20-year period and to affect the ITP would be considered "Changed Circumstances." Events not reasonably expected to occur, or anticipated to occur less frequently than once during an average 20-year period (such as a drought worse than the DOR) would be considered "Unforeseen Circumstances." For Changed Circumstances reasonably related to the Covered Activities and the proposed conservation measures in the District HCP, the District includes in this section a specific proposed response plan, in keeping with 50 CFR §17.22(b)(5)(i) for such Changed Circumstances. Except as noted in the subsections below, the contingency actions described as part of the response plan are able to be implemented within the funding commitments of the District discussed in Section 8, District HCP Funding Assurances, by reprogramming internal labor of District staff and/or certain contracted support.

7.2.2.1 Listing of New Species Not Covered by HCP

The listing of a new species by the Service as threatened or endangered within the ITP Area and that is determined to be not covered by the District HCP may constitute a Changed Circumstance. The two ecoregions of the HCP Planning Area have numerous vulnerable aquatic and terrestrial species (see Appendix A for a current listing), but none of those vulnerable species (or others) are known to exist in the ITP Area. The Service is statutorily required to notify the District and/or publish notice in the Federal Register upon becoming aware that a species associated with the habitats in Barton Springs and not a Covered Species (but rather an "Uncovered Species") that may be or has been proposed for listing.

Proposed Response:

a. Upon receipt of notice of the listing of an Uncovered Species, the District will seek to partner with the Service regarding confirmation of this circumstance as a Changed Circumstance for the District HCP as determined by the Service, and the necessity of modification and amendment of the District HCP. If the District elects to pursue amendment of the applicable permit, the District will ask the Service to provide technical assistance to the District in identifying any modifications to the District HCP warranted by the Changed Circumstance and necessary to amend the applicable federal permit.

b. The District shall assess the efficacy of the conservation and mitigation measures as already provided in the District HCP as they provide for avoidance, minimization, and mitigation of take of the Uncovered Species, and provide that analysis to the Service.

c. The District shall seek guidance from the Service in determining whether any further conservation or mitigation measures are required and whether the District ITP requires an amendment to authorize any incidental take of such Uncovered Species.

d. The District shall provide the Service with an assessment of whether the District's Covered Activities and the proposed response to the listing of the Uncovered Species will adversely affect take of Covered Species, consistent with Section 10 of the Act.

e. The District will incorporate into its amended HCP and ITP any needed conservation measures that are within its regulatory authority and financial capability.

7.2.2.2 Drought with Sustained, Unexpectedly Low DO Concentrations

It is conceivable, though not likely, that a range of drought and non-drought springflows during the term of the ITP could show DO concentrations related to springflows that were substantially different and/or significantly more adverse to the Covered Species than now anticipated on the basis of current knowledge; current knowledge that has been developed over more than a decade from existing data, models, and inferred relationships. If this were to occur on a systemic, sustained basis without other apparent external causes, the District would propose that this be considered an Unforeseen Circumstance. However, it is also possible that severe drought during the term of the ITP could suddenly degrade the habitat substantially more than anticipated in this HCP on a shorter-term, rapid-onset basis and in a way that had immediate adverse consequences for the Covered Species. This circumstance would be considered a Changed Circumstance. It would be associated with a persistent, declared Stage III-Critical or more severe drought condition, indicating the likely relationship of DO concentration to springflow, and would be triggered by confirmed daily mean DO concentrations in the outlets of Main Springs and/or Eliza Spring less than 3.4 mg/L, the laboratory LC_{50}, for more than 1 month. Such a scenario would eliminate transient and non-springflow-related causes of low DO concentrations.

Proposed Response:

Following consultation with the Service as to the need for immediate and extraordinary mitigation, the District Board could provide one or both of two sequential responses:

a. If the DO Augmentation Project, developed as a Mitigation Measure (see Section 6.2.2.2, Mitigation Measures) proved feasible and had been implemented in its planned stand-by mode at the time of this circumstance, the Board would trigger its implementation under the terms of its Implementation Agreement with the COA. The District would then monitor DO concentration in the outlets of Main Springs and Eliza Spring until the extraordinary stress on the species is relieved, as indicated by weekly average DO concentrations in those outlets greater than 4.5 mg/L, the NOAEL, on a sustained basis.

b. If the DO Augmentation Project could not be implemented for any reason or failed to provide the intended benefit, the Board is committed to induce selected individual permittees that have unused alternative water supplies to voluntarily agree to temporary withdrawal curtailments greater than otherwise required by District Rules. These curtailments would continue until the extraordinary stress on the species is relieved, as indicated by weekly average DO concentrations in the outlets of Main Springs and Eliza Spring greater than 3.7 mg/L, the LC_{25}, on a sustained basis. The inducement for such temporary curtailments could be temporary increases in the permittees' permitted volumes once drought ends. This provision would require a change in the District's Rules but not its MP, to be initiated upon ITP approval for ready implementation.

7.2.2.3 Substantial Change in Statutory, Legal, or Financial Means to Execute Conservation Measures According to ITP

A change in the District's legal authority or a substantial reduction in the level of annual revenues available to the District for implementation of the District HCP may constitute a Changed Circumstance. The District depends on annual revenues from usage fees derived from production permits, based on statutory authority granted by the Texas Legislature, and also from prescribed contributions by the COA under a statutory mandate. These revenues may vary somewhat each year, as explained in Section 8, District HCP Funding Assurances, and they are not anticipated to be curtailed or terminated during the course of the ITP; but neither are they guaranteed sources or amounts of revenue. GCDs are currently the Legislature's preferred means of managing groundwater, but the scope of this authority is subject to both legislative pressures and constitutional challenges in court. It is foreseeable that during the term of the HCP, legislative changes could affect both the District's legal authority and its level of annual revenues; and legal defense expenses, such as noted in subsection 7.2.1.7, Recent Texas Court Decisions and Aftermath, could adversely affect the District's financial condition. However, the District maintains funds in a contingency account to provide protection from emergency conditions affecting its revenues or expenses, and it will use them as needed to maintain the necessary funding of conservation measures and other ITP requirements.

Proposed Response:

If the District's statutory authority was substantially reduced, or its normal annual revenues were curtailed by more than 25 percent, or its non-labor-related expenses net of capital expense increased by more than a factor of 1.5 in any 2-year period (but not to a level at which the District would be unable to maintain the funding levels specified in the District HCP), the District will notify and enter into consultation with the Service. The purpose of the consultation would be to analyze the impact on proposed take of the Covered Species, prioritize response measures, and resolve the Changed Circumstance as it relates to take. Alternatively, following consultation and Board action, the District may request the Service to amend the District ITP and HCP.

7.2.2.4 Other Changes in Circumstances

Other changes in circumstances are foreseeable and might affect the status of the Covered Species. For example:

- Intentional, illegal human activities (for example, vandalism; terrorism) that are destructive to the Covered Species and/or their habitat.

- Major accidental pollution in the ITP Area (for example, toxic chemical spills; wastewater spills; petroleum and petrochemical pipeline leaks) that is destructive to the Covered Species and/or their habitat.

- Acute effects from increased pollutant discharges from either point sources, nonpoint sources, or both.

- Floods, erosion, and sedimentation of Barton Creek that, via a single event or by cumulative effect, degrade the health of the Covered Species or adversely change the quality of their habitat throughout a substantial part of their distribution.

- Changes in factors other than physical conditions and non-living resources that affect organisms (for example, increased predation and inter-species competition that alter ecological conditions).

- Decreased recharge to the Aquifer arising from smaller base flows in the creeks in the Contributing Zone over time, owing to the effects of climate change and especially the impacts of withdrawals up-gradient that reduce the amount of groundwater from the Trinity Aquifer discharging to those streams.

- Alternative water-supply benefits in the form of prospective reduced withdrawals from the Aquifer are not realized.

However, unlike other changes identified in the subsections above, these changes are not related to the Covered Activities, and the District is not able to address them directly as they are not within the statutory authority of the District; nor does the District have the financial resources for their remediation or even evaluation. Accordingly, these are not considered Changed Circumstances for the District HCP, and no specific contingency plan is provided in this HCP as part of the proposed response to other changes.

Proposed Response:

Should events or changes such as these occur, each will be evaluated jointly by the District and the Service as to significance to the Covered Species and confirm whether or not they are, in fact, Changed Circumstances and circumstances that the District is able to address. It is also anticipated that the District will coordinate with the COA in making such evaluations, as the changes could represent Changed (or Unforeseen) Circumstances under the Barton Springs Pool HCP as well.

7.3 Unforeseen Circumstances

The Service defines the term "Unforeseen Circumstances" to mean "changes in circumstances affecting a species or geographic area covered by [an HCP] that could not reasonably be anticipated by plan developers and the Service at the time of the HCP's negotiation and development and that result in a substantial and adverse change in the status of the covered species" (50 CFR §17.3). Such circumstances are not "unimaginable," just not reasonably expected during the term of the ITP. Unlike identified Changed Circumstances, the Service rather than the Applicant (the District) is responsible for Unforeseen Circumstances and responding to them. In addition, the necessity to make amendments, clarifications, and minor administrative amendments to the ITP and HCP forms a special class of Unforeseen Circumstances.

7.3.1 Responding to Unforeseen Circumstances

In making the determination that such an event constitutes an Unforeseen Circumstance, under its statutory obligations the Service will consider, but not be limited to, the level of knowledge about the affected species and the degree of specificity of the species conservation program under the District HCP. The Service also will consider whether failure to adopt additional conservation measures within the District's regulatory authority and financial ability would appreciably reduce the likelihood of survival and recovery of the affected species in the field.

7.3.1.1 Procedure for Determining Occurrence of Unforeseen Circumstances

In making a determination regarding the occurrence of any Unforeseen Circumstance, the Service has developed and will follow the procedures set forth in its applicable regulations (50 CFR 17.22(b)(1)(iii)). These are summarized below, but the statutory language is controlling:

<u>Notice to Applicants and Participants</u>
The Service shall provide written notice to the District together with a detailed statement of the facts regarding the Unforeseen Circumstance involved, the anticipated impact thereof on the Covered Species and its habitat, and all information and data that support the allegation. In addition, the notice shall include any proposed conservation measure(s) believed to address the Unforeseen Circumstance, an estimate of the cost of implementing such a conservation measure, and the likely effects upon (a) the District and its permittees, and (b) the existing plans and policies of any involved federal or state agencies.

<u>Responses as a Result of New Information Derived Through Adaptive Management</u>
The research and investigative measures that the District commits to undertake as a part of its adaptive management efforts may indicate or otherwise call for specific other responses to Changed or Unforeseen Circumstances. As new information is obtained during the course of the ITP period and in consultation with the Service, the District and the Service may agree to modify or redirect existing conservation measures to mitigate the effects of Unforeseen Circumstances, within the scope of existing approved and funded conservation actions and ITP terms. To the extent that these modified or redirected conservation measures do not affect conservation of other species or habitats, this approach may be deemed an adequate response to the Unforeseen Circumstance. However, if the proposed modifications or redirected conservation actions could affect the conservation of another Covered Species or its habitat, the procedure outlined below will be followed.

Submission of Information by Others
The District shall have a meaningful opportunity to submit information to the Service and shall do so within 60 days of the written notice, as provided above. Upon the written request of the District or any other participant in the District HCP, the time for submission of said information may be extended by the Service, and the request will not be unreasonably denied.

District Review
Within 90 days after the close of the period for submission of additional information, the District shall assess (a) the alleged Unforeseen Circumstance, (b) the proposed additional conservation measure(s), (c) its effects upon the Covered Species and its habitat and the economy and lifestyles of the District and permittees, and (d) possible alternatives to the proposed additional conservation measures that would result in the least adverse impacts upon the economy and

lifestyles of the District and permittees, while at the same time leading to the survival and recovery of the Covered Species.

Findings
The Service has the burden of demonstrating that an Unforeseen Circumstance has occurred, and that such Unforeseen Circumstance is having or is likely to have a significant adverse impact on Covered Species or its habitat. The findings of the Service must be clearly documented and be based upon the best scientific and commercial data available regarding the status and habitat requirements of the species. In addition, based on the results of its own expedited analysis of the Changed or Unforeseen Circumstance and the information provided by the District or other participants in the District HCP, the Service must provide the justification and approval for any reallocation of funds or resources necessary to respond to the Unforeseen Circumstance within the existing commitments of the District under the District HCP.

7.3.1.2 Response to Determination of Unforeseen Circumstances

In accordance with the Service's statutory authorities and obligations, which are controlling (50 CFR 17.22(b)(1)(iii)), after the conclusion of the process outlined above, the Service would determine that an Unforeseen Circumstance has occurred, and that additional conservation measures are likely required to address the circumstance but are not contemplated or capable of implementation by the District HCP. Then, provided that the District has fully complied with the terms of the District HCP, any proposed additional conservation measures by the District would be limited, to the maximum extent possible, to those within the terms of the District HCP and its ITP.

Under the Service's "No Surprises" rule, additional conservation measures may not require the payment of additional compensation by the District or its permittees. If additional expenditures are required, the Service or any other federal agency must take additional actions that might lead to the conservation or enhancement of a species that is being adversely affected by an Unforeseen Circumstance. The costs of these additional actions are intended to be borne by the Service or any other federal agency. However, prior to undertaking or attempting to impose any actions or conservation measures, the Service may consider all practicable alternatives to the proposed conservation measures, and adopt only such actions or conservation measures that would have the least effect upon the economy and lifestyle of the District and permittees, while at the same time addressing the Unforeseen Circumstance and the survival and recovery of the affected species and its habitat. The purpose of this provision is to recognize that Congress intended, even in the event of unforeseen, extraordinary, or Changed Circumstances, that additional mitigation requirements not be imposed upon a Section 10 permittee who has fully implemented the requirements undertaken by it pursuant to an approved HCP.

7.3.2 Clarifications, Minor Administrative Amendments, and All Other Amendments

Circumstances may arise that necessitate HCP and/or ITP amendments. Such circumstances have been interpreted by the Service to be a special category of Unforeseen Circumstances that may be triggered by either changed or other Unforeseen Circumstances or otherwise, and therefore must comply with the requirements of 50 CFR 17.22(b)(1)(iii): “the procedures to be used to deal with unforeseen circumstances.”

Amendments may include those actions or decisions that would affect the scope of mitigation or method of implementation of the District HCP or ITP and would require consent of the Service. Generic examples of amendments include but are not limited to the following (although none are currently planned or imminently envisioned):

- Addition of parties to the ITP;
- Changes in the ITP areal boundaries, with possible material effect on Barton Springs flows during Extreme Drought;
- Additions to or deletions from the species protected under the HCP;
- Changes in state or local legislation that materially diminish the authority of parties to the ITP to carry out the terms and conditions of the ITP;
- Changes in the conservation, monitoring, compliance, or enforcement programs likely to affect the level of incidental take of species; and
- Renewal of the ITP beyond the initial term.

In considering whether a prospective amendment is a minor or a major amendment of the existing ITP, the District will provide the Service with its analysis of whether the prospective take of the Covered Species would increase, decrease, or stay the same with the amendment, and the basis for that assessment. The District will then seek to consult with the Service as to its concurrence with the findings of that analysis. Any amendment that increases take is to be considered a “major amendment” under the Service’s statute, requiring execution of the procedures described in subsection 7.3.2.2, All other Amendments, before the amended ITP would be approved and issued. Further, renewal of the ITP beyond its then-current term or the issuance of a new ITP for the Covered Species will trigger a review under National Environmental Policy Act (NEPA) and by rule is considered a major amendment.

7.3.2.1 Clarifications and Minor Administrative Amendments

From time to time, it may be necessary for the Service and the District, as Administrator of the District HCP, to clarify provisions of the District HCP or the ITP to deal with issues that arise with respect to the administration of the process. Or the District may find it necessary to be more specific regarding the precise meaning and intent of the language contained within the HCP or ITP documents. Clarifications do not change the provisions of any of the documents in any way but merely clarify and make more precise the provisions as they exist.

The District HCP may, under certain circumstances and at the discretion of the Service, be amended without amending its associated ITP, provided such amendments are minor or technical and that the effect on the species involved and the levels of take resulting from the amendment are not increased from those analyzed when the ITP was issued.

In addition, from time to time it may be necessary to make Minor Administrative Amendments to the documents that do not make substantive changes to any of the provisions but that may be necessary or convenient over time to represent the overall intent of the District and the Service. Clarifications and Minor Administrative Amendments to the documents may be approved by the Field Supervisor of the Austin Ecological Field Office of the Service; and after review by the

District, the General Manager, or President of the Board of Directors of the District, shall be formalized by letter agreement or by substituted Plan Documents modified to contain only the Clarification or Minor Administrative Amendment.

7.3.2.2 All Other Amendments

Except as provided for in Clarifications and Minor Administrative Amendments in the subsection above, and subject to the Service's concurrence with the District's assessment of changes in take for an existing ITP, all other amendments are considered major amendments and will follow the procedures summarized in this subsection. The District HCP, ITP, or any (future) Implementation Agreement with other parties may not be amended or modified in any way without the written approval of the District (as Administrator of the District HCP), all signatories (currently, only the District), and the Service. All proposed material changes or amendments shall be reviewed by the District. Material changes shall be processed as an amendment to the permit in accordance with the provisions of the Act and regulations in 50 CFR Parts 13 and 17, and shall be subject to appropriate environmental review under NEPA provisions.

Amendments of the District HCP and ITP permit would be required for any change in the following: (a) the listing under the Act of a new species not currently addressed in the HCP that may be taken by project actions; (b) the modification of any project action or mitigation component under the HCP, including funding, that may significantly and adversely affect authorized take levels, effects of the project, or the nature or scope of the mitigation program with the exception of those plan modifications specifically addressed in the original District HCP and ITP application; and (c) any other modification of the project likely to result in significant adverse effects to the Covered Species not addressed in the original District HCP and ITP application.

Amendment of a Section 10(a) permit must be treated in the same manner as an original ITP application. ITP applications typically require a revised HCP, a permit application form, an Implementing Agreement if another Plan Applicant is added, a NEPA document, and a 30-day public comment period. However, the specific documentation needed in support of a permit amendment may vary depending on the nature of the amendment.

Proposed amendments to the District HCP or ITP can be initiated by the District or Service, or by other participating entities executing an Implementing Agreement, if they are approved for addition after the initial ITP and HCP are authorized. A proposed amendment would be submitted as a formal proposal to the District and Service for possible action. The proposal must state the reason the amendment is being requested, description of the proposed change, and an analysis of the potential effects of the proposed revision on the Covered Species and the terms and conditions of the ITP. Additional information may be requested. The approval process is as follows:

- Action on a proposed amendment under the District's jurisdiction must first be taken by the District. In a timely manner, the District Board must approve or deny the request,

- The plan amendment would be referred to other potentially affected Section 10(a)(1)(B) permit holders (here, the COA) for review and comment, and

- A plan amendment approved by the District Board (and any other parties to a future Implementation Agreement, if any) would then be forwarded to the Service for action consistent with its rules, regulations, and policy.

As specified by Service regulations, the same procedure would be followed when plan amendments are initiated by the Service, such as listing of a new species that could result in a change to the District HCP terms and conditions.

8.0 District HCP Funding Assurances

Essentially all of the HCP measures to be put into practice by the District (including the prospective avoidance, minimization, mitigation, and monitoring measures and their administration) are now specified in and authorized by the District's revised, approved Management Plan (MP) (BSEACD, 2013). Most of the direct measures called for in the HCP, including the District's well permitting and drought management programs, are already part of the MP and annual budget. As such, the funding for these measures over the 20-year term of the District HCP constitutes a significant share of the District's annual operating budget that is already being expended in these efforts. The District's budgeted revenue is based on water-use fees from permittees and other related fees that are authorized statutorily and collected from the District's groundwater production permittees; and also from a statutorily mandated, substantial supplemental fee paid by the COA, the amount of which is linked by formula to the water-use fees paid by the permittees. These revenues will be augmented from time to time by enforcement penalties and by other external funds for special initiatives, such as grants, neither of which are under District control and therefore are not considered a part of the sustainable operational funding of the District. Accordingly, because the entire continuing-operations budget of the District is by law established to serve the District's statutory purpose through implementation of the District's MP (and nothing else), a major share of the normal District operating budget provided by continuing water-use fees paid to the District by its permittees and supplemented by the COA will in effect be committed to implementing the HCP incorporated within the MP.

Because the HCP conservation measures are integrated with the Covered Activities, in that both are groundwater-use management, it is not possible to differentiate funds for groundwater management between Covered Activities and conservation measures. Similarly, there is no separate or additional funding represented by the conservation measures in the HCP and the pre-HCP periods; the difference is not how much is being spent but how those funds are being used. Simply put, the District's regulatory program has evolved over the past decade such that the District funds now support a much more effective groundwater management program than the program that existed before the HCP, for essentially the same amount of dollars.

The District HCP conservation measures, including the overhead associated with their provision, will require a variable expenses year to year, but always substantially more than one-half the total funding of the District's MP. Some flexibility in annual funding of the HCP is needed by the District to ensure its continuing operations, which also contributes to the variability in expenditures among the years. The actual level of effort and that portion associated with the HCP are expressed by the composition of each annual budget, which is already being used by the District to defray the costs of the personnel, programs, and special projects required to implement and manage most of the conservation measures in the proposed HCP, as they are integrated with the Covered Activities. The component parts of these budgets related to the HCP may also vary from year to year in the types of expense involved. Because of these factors, the District considers it more appropriate to commit to some minimum level of annual funding associated with the HCP conservation measures, rather than an average level or the specification of an exact amount each year of the ITP.

The District is committed to fully implementing the proposed HCP and meeting ITP requirements. Therefore, the District stipulates funding of the District HCP via its MP elements during the term of the ITP will be no less than 60% of each year's annual budget that is derived from its statutorily authorized annual operating revenues related to Aquifer use (that is, not including use of financial reserves). For example, in fiscal year 2014, the District's Board-approved annual budget is approximately $1,717,000, of which $198,000 is from reserves, so the nominal HCP Funding Commitment would be $911,000. In most years during the term of the ITP, the actual dollar value of expenditures for the HCP will be substantially greater than this minimum amount, as the MP would be carried out robustly. The funding by the District includes both in-kind labor provided by District staff and directors, and cash contributions and expenditures for other goods and services, all in support of the HCP conservation measures. The District's annual financial audit report will document actual operational expenditures as being equal to or greater than the percentage-based commitment to funding groundwater management and conservation under the HCP.

Barring significant changes in the statutory authorities and/or legal landscape, which would likely require a major amendment to the ITP and the HCP, the District anticipates being able to continue annual funding from these sources in that same or greater amount because the revenue is statutorily authorized. State law requires the District's expenditures to be approximately equivalent to its revenues (which may include use of financial reserves) each year. However, also by State law the District cannot commit funds in advance to any purpose except those budgeted each fiscal year, and it is allowed to budget for only 1 year at a time. These restrictions notwithstanding, it is the District's intent, as demonstrated by its Board's agreement to the ITP terms, to continue to fund all the activities that support the District HCP measures in the committed amount, as a minimum, throughout the life of the ITP and HCP. The District will report the actual funding provided for implementing the HCP each year in its annual implementation monitoring report to the Service.

The District will implement the HCP program in the form of District labor, program expenditures, and/or cash each year for the aggregated HCP program in that year, which will include various measures that may be individual, time-phased projects active in that year. For example, in the third year following ITP issuance, some of the HCP funding might be earmarked to fund two project-oriented measures that are active in the third year—say, one research project and one mitigation initiative.

Specific conservation-, research-, and mitigation-project measures will be identified and funded in the out years, as other collaborating parties are identified and become involved, as required funds from other parties are committed, and/or as participation agreements are negotiated. However, the actual years and the committed amounts (of in-kind and/or cash contributions) under which any specific project measure is undertaken are largely indeterminate because the ability and efficacy to conduct those project-oriented measures and the timing of them are uncertain. The District will identify in its HCP annual report those specific conservation, research, and mitigation projects that have been and/or will be initiated and the project-specific District in-kind services and funding (and funding from other sources, if applicable) that are planned for the then-upcoming year(s), once such clarity is available during the course of the ITP term. Similarly, if, say, because of exigencies beyond the District's control some planned project was unable to be started when planned and/or was not able to be funded at the planned level in one or more years, the District would explain the source of the deviation from plan in its implementation monitoring report to the Service. Provided the Service subsequently determines that explanation to be adequate and that the overall District funding commitment is achieved, such deviation from the planned funding is proposed to not require an amendment to the HCP/ITP.

9.0 Alternatives to Taking

The Endangered Species Act (Act) requires that each HCP address "the alternative actions to [the proposed incidental] taking the applicant considered and the reasons why such alternatives are not being utilized."

The Covered Activities in this HCP relate exclusively to groundwater withdrawals by third-party well owners and the District's own regulatory program concerning such withdrawals, which are superimposed on the natural variability of the Aquifer. The natural variation in Aquifer storage and springflow together produce a condition in which <u>any</u> amount of groundwater withdrawal during severe drought will constitute take. There is no alternative action that allows use of the Aquifer as a water supply without producing take of the Covered Species for substantial periods of time. Accordingly, any alternative that could completely *avoid* take of the Covered Species would require imposition of a regulatory program by the District that allows <u>no</u> use of the Aquifer as a water supply during drought.

9.1 Analysis of Potential Alternatives to Avoid Take

Two basic options were considered by the District in assessing the efficacy of an alternative approach that could eliminate the use of the Aquifer as a water supply and thereby avoid, not just minimize, take: reduction in demand for Aquifer water, and water-supply enhancement and substitution. Under certain conditions, each of these, either individually or in combination, could constitute an alternative to taking; they are evaluated in the following subsections.

9.1.1 Demand Reduction Alternative

The District's authority allows it to mandate reductions in demand for Aquifer water, but only in a limited sense. The District's permitting program provides the means by which withdrawals from the aquifer by large-capacity wells and other wells of certain types can be controlled, both in absolute-use terms and especially in response to drought conditions. These regulatory curtailments, backed with effective enforcement to ensure compliance, provide a non-structural, assured means for preserving the water levels in the aquifer, which benefit well owners/users in the western part of the District where saturated thickness of the Aquifer is relatively small; and also, of critical importance to the HCP, such curtailments will benefit the flow and the DO concentration of water issuing from Barton Springs, which is the habitat of the Covered Species.

However, the District's authority does not extend to ordering complete cessation of withdrawals from all wells in the Aquifer, even during Extreme Drought. Under State law and recent court interpretations, landowners have a vested property right to withdraw groundwater under their land as a real property interest. Further, the District's regulatory program is supported by permitting that is based on actual, reasonable and non-speculative demand such that there is very little permitted pumping that is not committed to being fully used for beneficial purposes, especially after factoring in severe drought curtailments. So the Demand Reduction Alternative *per se* legally and practically must allow some amount of existing and future freshwater Edwards Aquifer groundwater withdrawals from wells to continue. The Aquifer has been designated as a "sole-source water-supply" for many residents in the ITP Area, which imposes certain protections and considerations applicable to other federal programs, including those of the

Service. District regulation-mandated curtailments during drought that minimize but do not prevent withdrawals and that are authorized under an ITP would be consistent with applicable state and federal statutes. Such an alternative mitigates but does not avoid take (EPA, 1988).

9.1.2 Supply Enhancement and Substitution Alternative

During drought, if the District could mandate that all Aquifer users stop pumping their wells during drought in favor of switching completely to another, standby supply, then the wells in the Aquifer would not be decreasing springflow and increasing the amount and frequency of take. The enhanced availability of alternative water supplies would facilitate and allow substitution for Aquifer water. But as explained below, this Supply Enhancement and Substitution Alternative *per se* is not statutorily, economically or even physically feasible in aggregate for all groundwater users across the District. The District is not legally authorized to make such demands on its permittees, or even to require its permittees to develop alternative water supplies.

Some well-resourced permittees have voluntarily broadened their water-supply options to include alternative sources of water, and some of them voluntarily curtail their withdrawals from the Aquifer during drought and use substitute supplies. But there are simply not enough firm-yield alternative water supplies available now to all groundwater users, either at any price or at something less than prohibitive cost for their situations. In any event, the District cannot legally mandate such substitutions *per se* for existing, authorized supplies of Aquifer groundwater. The District can only encourage and incentivize acquiring such replacement water by its scientific investigations and regulatory programs. With one minor exception, the District does not own any alternative water rights, and its financial resources do not allow it to acquire others, at least on the scale that would meaningfully affect springflow.

The District is actively working with its stakeholders, especially its permittees that are water-supply providers, and with others to foster development of alternative supplies of water. The District's regulatory programs can be a driver in that. The proposed alternative can work for some permittees in concert with the Demand Reduction Alternative described in the previous subsection to provide a means for greater curtailments while meeting water demands, or a greater likelihood of being able to meet the regulatory required curtailments. As new water supplies become available, for example through desalination of brackish groundwater, aquifer storage and recovery, and water reclamation, there will be increased opportunities to substitute those supplies for Aquifer water. But the time frame for new supplies is not immediate, they are not likely to be available over a wide geographic area, and they will be much more expensive than greatly undervalued and underpriced freshwater Edwards Aquifer water. Even if new supplies were technologically possible, the District does not own or control those alternative water resources, and if it did, the cost of alternative supplies that could provide complete replacement of Edwards Aquifer water is orders of magnitude greater than the District's existing and likely future financial resources. So for those reasons, while the Supply Enhancement and Substitution Alternative might support an option that is mostly based on demand reduction in something of a hybrid way on a case-by-case basis, it is not *per se* an alternative that could be used as the primary, preferred option in the HCP and avoid take.

The District has for years also worked to enhance the amount of recharge that can enter the Aquifer through its natural openings in streambeds to maximize the amount of water available from natural rainfall and runoff. It continues to preserve if not increase the recharge capacity and prevent the discrete recharge features from getting clogged with sediment-laden runoff. However, few of those features are available to the District for such operations, too few to make a real difference as *additional* supply. And the same dearth of alternative water supplies described above prevents introduction of such alternative water into the recharge features during severe drought conditions, which is when the additional supply is most needed.

Although structural projects and alternative water-supply projects such as those described above can be important in management of the Aquifer, such activities are typically not under District control or always available to the District. Provision of the entire volume of currently permitted withdrawals (nearly 2.9 billion gallons annually) with alternative water supplies from non-Aquifer sources to even the current (2014) Aquifer users would be prohibitively expensive (into the hundreds of millions of dollars); and no mechanism is available to the District to recover most such costs. Thus, to a substantial extent, the District cannot afford the level of infrastructure development that would replace all of the current water supplies of the Aquifer and allow large-scale substitution of water supplies. Without such complete substitution with alternative water, take of the Covered Species would continue during drought periods. Moreover, the District has no legal authority to force an existing groundwater user to stop using that groundwater supply in favor of another. Further, the District cannot legally, unilaterally reduce the property interest in groundwater from the Aquifer even if a substitute supply is provided.

9.2 Basis of Proposed Groundwater Management Program

The District has concluded that the primary option that produces the needed balance between legal groundwater withdrawal/use and conservation of the Covered Species is the non-structural regulatory program that constitutes the Covered Activity; that is, the Enhanced Best Attainable Alternative described in Section 6, Conservation Measures. The basis for this determination and selection is discussed in this section.

The District is a political subdivision of the State of Texas, a groundwater conservation district (GCD) charged by the State legislature to preserve, conserve, protect, and prevent waste of the groundwater resources within its jurisdictional area, and to allow use of the groundwater resources to the maximum extent feasible by well owners in that area. More importantly, the District is the only governmental entity that is able to serve that mission, as the groundwater is owned by the surface landowner, rather than the State or the public, and the landowners have a legal right to withdraw water from the Aquifer for their own beneficial uses. Without the District's programs, groundwater withdrawals in the District would be unregulated and discharge from Barton Springs would not be managed, raising the specter of zero springflow for periods of many months during Extreme Drought. And without the District's regulatory restrictions, there would be no control on the impacts of springflow-induced stress on the Covered Species.

Further, the District as a GCD has a legal requirement to manage the groundwater and protect other related natural resources, including the Covered Species at Barton Springs. An ITP's required HCP offers a vehicle that can provide longer-term, more systematic assurance of such protection than would otherwise be available to the District without the permit. It also provides a legal shield for not only the District but its permittees against claims that could otherwise be asserted against them, as they exercise their legal right to use their "fair share" of groundwater under the Act, which obligates real property owners to protect endangered species.

Within this selected approach are options related to balancing risks to continued District operations and rewards in terms of aquifer and habitat protection, which the District developed over time for this HCP as described in Section 4.1.2, Historical Perspective of Covered Activities. The District Board considered several of the intermediate steps as potential options for the HCP program, each having differing levels of curtailment and resulting springflow but also with differing implementation challenges and probabilities of success. But ultimately the Board determined that the District had an obligation to provide the maximum protection to the endangered species that it legally and financially could, so the only acceptable optional level of demand reduction in the final analysis is the Enhanced Best Attainable Alternative aided by alternative-supply enhancement and substitution where feasible. This alternative comprises the minimization, mitigation, and adaptive management measures described in Section 6, Conservation Program. There is a practical limit on how much regulatory curtailment of water use by any one permittee is feasible, and also a legal and financial limit on how much curtailment is "reasonable" and "fair," before a *regulatory* taking ensues that arguably represents compensable loss to the groundwater owner/user. The Board considers the current expression of this option at that limit, which constitutes conservation measures equivalent "to the greatest extent practicable."

The Enhanced Best Attainable Alternative, based on a hybrid of demand reduction and alternative supply development, is considered the preferred and proposed option for groundwater management in the District that affects the Covered Species, both now and over the term of the ITP. At its maximum curtailment expression, this alternative, which constitutes the Covered Activities, essentially results in water levels and springflows that would meet the Desired Future Condition of the Aquifer, which is specifically implemented to minimize take during a recurrence of the drought of record (DOR) to the maximum extent feasible.

In summary, the Covered Activities of this HCP provide the primary vehicle to minimize the risks of both incidental take of the Covered Species and compensable regulatory take of real property. The District's regulatory program is the only statutorily authorized option that the District can use to balance both, and therefore it is considered the principal option for groundwater management in the HCP.

10.0 Other Information That Secretary May Require

This section of the Habitat Conservation Plan provides assurance that no other information besides that contained elsewhere in this document is required to be presented for compliance with Section 10(a)(2)(A)(iv) of the Endangered Species Act. The Secretary of the Interior and the Director of the U.S. Fish & Wildlife Service have not identified other specific informational or other requirements of the District for this HCP at this time (2014).

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