SUSQUEHANNA RIVER BASIN COMMISSION
4423 N. Front Street | Harrisburg, PA 17110-1788 | 717.238.0423 | srbc.net
NY ▪ PA ▪ MD ▪ USA

DRAFT

Policy Number: **Policy No. 2021-xx**

Title: **Aquifer Testing Plan Guidance**

Effective Date: **xx**

Authority: Public Law 91-575, 84 Stat. 1509 *et seq.*, Sections 3.1, 3.4(2) & (8), 3.5(1) and 3.10, 18 CFR §§ 806.2, 806.4, 806.12, 806.13, 806.14, and 806.23.

Policy: The Susquehanna River Basin Commission (Commission or SRBC) established regulatory requirements for water withdrawals, including groundwater withdrawals, at Part 806, including general provisions, application procedures, standards for review and terms of approval. Section 806.12 details that, prior to submission of an application pursuant to 18 CFR § 806.13, a project sponsor seeking approval for a new groundwater withdrawal, a renewal of an expiring groundwater withdrawal, or an increase of a groundwater withdrawal, shall complete an Alternate Hydrogeologic Evaluation (AHE) when suitable aquifer testing or other data is already available, or perform an aquifer test to collect suitable data for evaluation

In its regulation of water withdrawals, the Commission intends to advance the purposes of the Compact, including the specific purposes of protection of public health, safety and welfare; stream quality control; economic development; protection of fisheries and aquatic habitat; recreation; dilution and abatement of pollution; the regulation of flows and supplies of groundwater and surface waters; the avoidance of conflicts among water users; and protection of the Chesapeake Bay (18 CFR § 806.2).

Purpose: This policy clarifies the regulatory requirements and procedures that should be followed by project sponsors regarding an aquifer test for most projects. The document provides guidelines for developing an implementable aquifer test plan that will produce suitable data and satisfy regulatory standards.

Applicability: This policy applies to the development of an aquifer test plan for review and approval by Commission staff before testing is undertaken.

Disclaimer: The policy outlined in this document is intended to supplement existing requirements. Nothing in this policy shall affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. This document establishes the framework within which the Commission will exercise its administrative discretion in the future and provides guidance for how the Commission will fulfill its regulatory review requirements. The Commission reserves the discretion to deviate from this policy statement if circumstances warrant.

Page length: 22 pages

I. Introduction

A. Purpose

Prior to submission of an application pursuant to 18 CFR § 806.13, a project sponsor seeking approval for a new groundwater withdrawal, a renewal of an expiring groundwater withdrawal or an increase of a groundwater withdrawal shall perform an aquifer test to collect suitable data for evaluation or complete an Alternative Hydrogeologic Evaluation (AHE) (Commission Policy 2021-XX) when suitable aquifer testing or other data is already available, in accordance with 18 CFR § 806.12.

The purpose of this document is to provide guidance to project sponsors and their consultants for the development of an aquifer test plan (Plan) and conducting an aquifer test, required under 18 CFR § 806.13, which must be reviewed and approved by Commission staff before testing commences. The Commission supports sustainable economic development in the basin and evaluates withdrawal applications for the long-term protection of water resources. In the absence of other suitable data, aquifer test results are used to help evaluate the aquifer, the local groundwater basin, and the production capability of the well to ensure that the resources are adequate to supply the needs of the project without significant adverse impact to other users or the water resources of the basin.

All withdrawal projects are subject to standards established in 18 CFR § 806.23, which include consideration of the following: lowering of groundwater or streamflow levels; groundwater and surface water availability, including the impact of cumulative uses; rendering competing supplies unreliable; affecting other water uses; causing water quality degradation that may be injurious to any existing or potential water use; affecting fish, wildlife, or other living resources or their habitat; causing permanent loss of aquifer storage capacity; affecting wetlands; or affecting low flow of perennial or intermittent streams. Commission review of a groundwater withdrawal can be assessed through three principal risk factors:

1. Sustainability of the withdrawal;
2. Impacts to other users, and
3. Impacts to the environment.

The Plan should be designed so that the resulting aquifer testing data will be sufficient for the project sponsor, their consultant, and Commission staff to thoroughly evaluate the project with respect to the three principle risk factors and for Commission staff to make recommendations to the Commission for action on the groundwater withdrawal application. Sustainability also encompasses an evaluation of source vulnerabilities that allow for a project to plan for adaptation measures to enhance source and system resiliency to changing water quantity, water quality, or climate conditions.

B. Description and Intent of Guidance Components

This document is structured to offer administrative procedures for the project sponsor's use, and provide detailed technical guidance and criteria for the professional consultant's use in developing a complete Plan. Part 1, which is primarily provided for the project sponsor, outlines the administrative framework within which the Plan should be initiated, general criteria for utilization of a professional consultant in Plan development and a section that a project sponsor should consider, called the Pre-drill Well Site Review. This is a voluntary technical assistance service that the Commission offers to a project sponsor prior to Plan development, in order to screen potential well sites for high-level concerns prior to investing resources in drilling a new well. Once a project sponsor has obtained the services of a consultant, the consultant should reference Parts 2 and 3 of this document, which are more technical and focused on providing guidance to consultants assisting sponsors. Part 2 guides the consultant through the development of the conceptual site model (CSM) portion of the Plan, including preliminary research and field work. Part 3 guides the consultant through the procedures, processes and monitoring location criteria associated with the development and implementation of an appropriate aquifer test. In development of the final Plan to be submitted to the Commission, it is expected that the project sponsor (owner of the project) is involved with and coordinates the consultant's work product through Parts 2 and 3.

Part 1 – Administrative Procedures
- Section I – Online Aquifer Testing Plan Form
- Section II – Consultants and Professional Licensure
- Section III – Pre-drill Well Site Review
- Section IV – Other Regulatory Agencies

Part 2 – Conceptual Site Model
- Section I – Project Description
- Section II – Hydrogeologic Description
- Section III – Groundwater Availability

Part 3 – Monitoring and Implementation
- Section I – Monitoring Guidance
- Section II – Procedures for Aquifer Testing

In using this document's guidance in Parts 2 and 3, the final Plan should describe the expected or current water use for the project, convey the pre-test understanding of the hydrogeologic conceptual site model for the study area, evaluate the groundwater resources available for development or use, and provide the procedures to which the aquifer test will adhere.

The Plan components and procedures described herein are sufficient for most projects. However, deviations from standard testing procedures may be needed for certain projects (e.g. wellfields) and should be discussed with Commission staff prior to planning the project. Should deviations from standard procedures be needed, the proposed testing procedures should be fully described within the Plan and justification for the alternative testing methodology should be provided. Please contact Commission staff for additional guidance on completing Plans with alternative testing procedures.

Part 1: Administrative Procedures

I. Online Aquifer Testing Plan Form

In 2016 the Commission developed an online aquifer test plan form to facilitate efficient preparation and submittal of aquifer testing plans (www.srbc.net). Please contact Commission staff before deviating from the online form. In addition to instructions developed for the online form, the Commission developed functional sample templates for all online forms that allow users to access and review the forms without starting a project specific form.

II. Consultants and Professional Licensure

The Commission recommends that a project sponsor retain a project hydrogeologist with substantial experience in the siting, drilling, testing, and permitting of water supply wells for the groundwater development project. Project sponsors may visit the Commission's website for a list of consultants who have participated in Commission training events; however, the list does not imply any endorsement regarding professional experience or appropriate professional licensure.

Project sponsors and consultants must comply with laws of member jurisdictions, including any professional licensing requirements. Aquifer testing plans, groundwater withdrawal applications, or submittals that provide geologic interpretation must be prepared and submitted by professional geologists in accordance with applicable licensing laws. Currently, pursuant to state law, project sponsors in Pennsylvania and New York submitting geologic interpretations must use the services of a licensed professional geologist legally qualified to practice in the respective state.

III. Pre-drill Well Site Review

Pre-drill Well Site Review (PDWSR) (Commission Policy No. 2021-0X) is a service offered by the Commission to assist a project sponsor in completing a preliminary screening of potential well sites to identify high-level concerns prior to investing the time, money, and effort in drilling a new well. The PDWSR is a voluntary screening process offered by the Commission to assist project sponsors in developing new groundwater sources in locations that minimize potential water resource conflicts while meeting the needs of the project. Much of the information that will be prepared for the PDWSR for a specific site can also be used for development of the Plan. Please refer to Commission Policy No. 2021-0X for guidance on completing and submitting a PDWSR to the Commission.

IV. Other Regulatory Agencies

Water supply projects may also be subject to review and approval by other regulatory agencies that may have requirements regarding aquifer testing. Specifically, Safe Drinking Water Act projects are subject to other state regulations and approval by those agencies is also needed. Projects are required to consult with other regulatory agencies to determine the applicability of other regulations to the project and may be required to obtain approval of the aquifer testing plan prior to testing or approval of the withdrawal prior to initiation.

Part 2: Conceptual Site Model

The Conceptual Site section of the Plan provides desktop-level descriptions and evaluations based on facility water use needs, literature reviews, water use within the groundwater basin, and pertinent hydrogeologic reports and data applicable to the project. This section also includes field collection of water level measurements, evaluation and development of a monitoring network, strike and dip measurements, and other observations, as applicable, to develop and support the site conceptual site model. The well should be in its final constructed form, including the final total depth and borehole diameter, with permanent casing set and grouted in place, and screened intervals set prior to finalizing and submitting a Plan.

I. Project Description

The Project Description component of the Plan is a desktop effort that provides general information regarding the project sponsor and the proposed withdrawal.

The description of the project should include:

1. Anticipated long-term owner and operator, if different;
2. Purpose for the well and use of the water to be withdrawn;
3. Current facility water demand (million gallons per day [mgd]);
4. Anticipated future facility water demand (mgd);
5. Expected or desired withdrawal quantity from the proposed withdrawal(s).

The project description should provide context for the proposed withdrawal so Commission staff can provide appropriate guidance for developing the new source. Commission staff use this information to better understand the need for the source and the overall project, including how the proposed withdrawal (for new projects) will be integrated with existing sources.

II. Hydrogeologic Description

A thorough understanding of the hydrogeologic setting and site conceptual site model is critical to developing the appropriate testing procedures, establishing reasonable expectations for testing results, and developing an appropriate monitoring network that will provide sufficient data and minimize testing costs. As part of any groundwater source development project, much of this work should be completed prior to committing to the expense of installing a well. A fully-developed and well-written hydrogeologic description provides the consultant with the opportunity to demonstrate that the Plan and monitoring network has been designed appropriately to collect the data necessary for staff to evaluate the sustainability of the withdrawal and potential for impacts to other users and the environment.

The hydrogeologic description should include:

- The topographic setting;
- Geologic structure(s);
- Identification of recharge and discharge areas;
- Dominant flow paths;
- A description of texture, mineralogic composition, and competence of the aquifer(s);

- The dominant permeability types; and
- Potential hydrogeologic boundary conditions.

Topographic and geologic maps, cross-sections, well logs, and groundwater contour maps developed from recent water level data are needed to complete and support the hydrogeologic description.

III. Groundwater Availability

The Commission expects and encourages through the offering of technical assistance with the completion of PDWSR, that the groundwater resource available for development will be evaluated well before submittal of an Plan to the Commission, thereby avoiding extensive drilling costs for sites with limited water availability. In accordance with 18 CFR § 806.23, the Commission will consider the aggregate and cumulative effects of existing and proposed withdrawals within a groundwater basin or watershed and may deny an application, or limit or condition an approval, based on limited water availability. Therefore, it is incumbent upon project sponsors to demonstrate that sufficient groundwater is available for the requested withdrawal to meet the needs of the project. Accordingly, 18 CFR § 806.12 provides that aquifer testing plans must include an analysis of groundwater availability during a 1-in-10-year drought recurrence interval. Proposed withdrawals that exceed the 1-in-10 year drought availability estimate will need a sufficient monitoring network to collect the data necessary to update the hydrogeologic conceptual site model and groundwater availability analysis to either verify the initial estimate or demonstrate that the contributing groundwater basin is sufficient to support the requested withdrawal. If the results of aquifer testing and the groundwater availability analysis do not indicate that sufficient resources are available, the project sponsor will need to re-evaluate the rate to be requested for withdrawal.

The groundwater availability analysis is a desktop level screening tool that should be used to assess the potential resource available for development locally. A Phase I groundwater availability analysis includes an evaluation of the contributing groundwater basin, groundwater recharge rates, and other users within the groundwater basin. If estimated use (proposed and existing withdrawals) in the recharge area exceeds 50 percent of the 1-in-10 year drought availability, then a Phase II groundwater availability analysis should be completed. The Phase II groundwater availability analysis refines the estimated water available for development and assesses the potential reduction of recharge resulting from impervious cover within the contributing basin. Additionally, the Phase II analysis includes discharges to surface water, which should only be incorporated into the analysis if surface water is expected to recharge the aquifer naturally or through induced infiltration as a result of the withdrawal.

A. Phase I Groundwater Availability Analysis

A Phase I groundwater availability analysis evaluates three aspects: contributing groundwater basin, groundwater recharge rates, and existing and proposed withdrawals. When considered together, the project can estimate the quantity of groundwater available for development.

1. Contributing Groundwater Basin

The contributing groundwater basin should conservatively estimate the contributing basin to ensure that sufficient water is available to support the requested withdrawal. To estimate contributing area, the local groundwater basin should be evaluated first, which usually starts with a topographic drainage basin. If supported by topography, groundwater flow direction, and geologic structure, the contributing basin can be expanded to a more regional scale. However, as the contributing basin is expanded, the project sponsor will need to evaluate the impact of other withdrawals within the expanded basin and how surface water and groundwater interact. The Phase I availability analysis should include a contributing basin map that identifies the estimated groundwater basin.

2. Recharge Rates

Groundwater recharge rates, based on 1-in-10-year drought recharge statistics or 60 percent of the average annual recharge rate (which approximates a 1-in-10-year annual drought), must be used in the analysis. Recharge rates should be selected based on published data for the local project area and should be specific to the geologic formation(s) present within the contributing groundwater basin, if possible. If multiple published recharge rates are available for a project area, calculations should be based on the best available recharge rate information.[1] Project sponsors should select the most appropriate specific recharge rate (not an average) of the published available rates, based on geology, topography, precipitations, baseflow separation method, and other factors. The rate selected should be fully justified and supported in the Plan.

3. Existing and Proposed Withdrawals

To account for other users in the contributing groundwater basin, the project should determine the location of all significant withdrawals. For withdrawals that discharge to on-lot septic systems, the combined net withdrawal can be assumed. For all other withdrawals not discharging to on-lot septic systems, the gross withdrawal should be used. For projects permitted by the SRBC or another agency, the maximum permitted rate should be used, as the project has the ability to utilize the approved water quantity. The locations of all significant groundwater withdrawals should be provided on the contributing basin map, but residential developments served by individual wells can be grouped by development.

B. Phase II Groundwater Availability Analysis

The Phase II groundwater availability analysis needs to be completed only if the Phase I assessment estimates existing and proposed groundwater utilization to exceed 50 percent. Therefore, the Phase II includes all aspects of a Phase I analysis, but also considers the impact that impervious surfaces may have on recharge and the effect of discharges within the contributing

---

[1] Commission staff is available to provide guidance on recharge rates and other groundwater availability related issues.

groundwater basin. Impervious cover could result in significant losses of recharge to the basin and must be estimated for the Phase II analysis.

Surface water discharges within the basin should also be considered, but not all surface water discharges can be considered an addition. Surface water discharges should only be used to offset withdrawals in settings where significant surface water/ groundwater interaction occurs and/ or it is likely that the groundwater withdrawal will have a direct impact to surface water flow. The location of all surface water discharges considered in the analysis should be shown on the contributing basin map.

Part 3: Monitoring and Implementation

Appropriate testing procedures and methodical implementation are needed to ensure the collection of meaningful data that provides Commission staff with sufficient information to assess the principle risk factors for withdrawals. Because many aquifer characteristics are not measured directly and are inferred or calculated from testing data, careful control and implementation of aquifer test procedures is of utmost importance. Accordingly, Plans should provide appropriate procedures to create constant or predictable conditions and eliminate as many variables as possible to reduce or eliminate the collection of specious, ambiguous, or inconclusive data. Procedures applicable to each phase of testing should be developed to ensure that the essential purposes of each phase of testing are completed correctly. Written procedures should be provided to all field personnel for reference during all phases of aquifer testing.

The following sections describe the testing procedures and monitoring needed to complete adequate tests. Please note that approval of a Plan does not guarantee successful completion of a test, nor does successful completion of test in accordance with an approved Plan guarantee approval of the project at the requested rate.

A. Monitoring Guidance

Aquifer testing plans should include a proposed monitoring network that should include, as appropriate, other groundwater wells and surface water bodies, including ponds, wetlands, streams, springs, and seeps to assess the proposed withdrawal for sustainability, potential impacts to other users, and impacts to the environment. The monitoring network should be focused on the expected area of influence during testing to adequately characterize drawdown in the k-max and k-min directions and where potentially significant impacts are most likely to occur. The monitoring network will also be used to assess the groundwater basin, refine the groundwater availability analysis included with the groundwater withdrawal application, and estimate aquifer conditions and theoretical drawdown throughout the area of influence after 90 days of pumping at the requested rate without recharge. This approach targets efficiency in accurate monitoring locations by minimizing excess or unnecessary monitoring locations and reduces the overall costs to perform an aquifer test. The Plan should depict the proposed monitoring network and include the specific technical standards associated with each type of monitoring, as provided herein.

1. Groundwater Monitoring

Appropriate groundwater monitoring should help a project evaluate each of the principle risk factors by collecting information that can be used to assess the sustainability of the sources, impacts to other users, and impacts to the environment. Although environmental impacts are often best assessed with direct surface water monitoring, groundwater monitoring can help evaluate the hydrogeologic setting and if the proposed withdrawal will have adverse impacts to the aquifer.

Wells monitored during the aquifer test will commonly be within 2,500 feet of the test well, but monitoring of wells beyond 2,500 feet may be required, especially in confined aquifer settings where pumping influence can propagate long distances during a test. In order to develop an appropriate monitoring network, an inventory of wells within 2,500 feet of the test well should be completed and provided with the aquifer testing plan. The inventory should provide as much information as is available including: location, well depth, depth to water, pump depth, and owner information. After the groundwater well inventory is completed, well construction details, water level information, and location of the wells should be evaluated to determine a monitoring network that will provide representative wells to evaluate potential impacts as a result of the proposed withdrawal to shallow and deep aquifers and wells. In many cases, monitoring of all existing wells is unnecessary and an appropriate subset of existing wells can be selected to provide adequate data for evaluation of the proposed withdrawal. Monitoring of actively used wells is acceptable, and may be preferable so that staff can evaluate projected drawdown as a result of operating the test well in conjunction with the use of the monitoring well.

Project sponsors and their consultants should consider monitoring wells beyond the area of influence to help establish background conditions in the aquifer. Projects that should consider this additional background monitoring include existing projects, projects with significant pumping from other wells near the test well, projects with limited nearby groundwater monitoring locations available, and projects where a majority of the monitoring locations pump frequently with significant drawdown that may interfere with assessing impacts.

It is the Commission's preference to utilize existing wells to develop adequate monitoring networks and avoid the cost of installation of new wells for monitoring. However, where sufficient characterization of the aquifer and potential impacts to other users or the environment are difficult to assess due to site conditions or lack of existing monitoring wells, the installation of monitoring wells may be recommended.

2. Surface Water Monitoring

A sufficient number of monitoring points should be selected to adequately characterize potential surface water impacts within the estimated area of influence and within approximately 2,500 feet of the test well. Monitoring of surface water features at distances greater than 2,500 feet may be required for the protection of sensitive, high-value surface water features. During the review of all aquifer testing plans, Commission staff will conduct a field meeting to evaluate potential surface water monitoring locations and assess if direct flow measurements are feasible or if installation of piezometers will be sufficient.

The selection of surface water resources to be monitored should be based on the distance from the well being tested, the proximity to high permeability features (fracture trends, gravel beds, etc.) that likely have an efficient hydraulic connection to the well being tested, and flow conditions at the time of testing.

<u>Ponds and Wetlands</u>

The method of monitoring ponds and wetlands is dependent upon whether or not flow exists at the time of testing.

Wetlands Without Flow.

Ponds and wetlands without flow should be monitored with wetland piezometers installed as hydraulically separated pairs of shallow and deep piezometers. The shallow piezometer should be screened within the root zone. The bottom of the screened interval should be at a depth between 12 and 18 inches below ground surface and the top of the screened interval should be open to the surface. The top of screen for the deeper piezometer should be at a depth of at least 2 feet below the bottom of the screened interval for the shallow piezometer and in the higher permeability unconsolidated materials below a confining layer of the wetland (if present). A functional bentonite seal should be present to ensure that the intervals are hydraulically isolated.

To aid in the determination of the final construction of the wetland piezometers and to better understand the wetland hydrology, the surficial materials in the area to be monitored should be investigated with a test borehole or examined in a natural exposure (streambank, ravine, etc.). The unconsolidated materials should be carefully logged for their physical and hydrogeologic characteristics (texture, structure, sorting, etc.). The descriptions should be used as the basis for determining the construction of the deep piezometers (i.e., the depth and length of screen).

Ponds Without Flow

Ponds that do not have inflow or outflow that can be monitored should be monitored with a staff gauge and piezometer installed near the pond to evaluate changes in the piezometric surface through the test. The bank piezometer should be installed adjacent to the pond and generally be completed at a depth of two to four feet and be sealed from the surface.

Ponds and Wetlands With Flow

Ponds and wetlands with flow should be monitored with an instrumented weir or flume as described below for stream and spring monitoring. Appropriate locations for flow monitoring will generally be in a discharge channel for wetlands and pond, but inflow monitoring may be appropriate. Depending on the size and sensitivity of the wetlands feature, nested piezometers may also be needed.

Streams and Springs (flowing surface water)

Whenever practical, direct measurement of stream flow, via an instrumented weir or flume, is preferred to assess impacts as a result of a proposed withdrawal. The flow of streams and springs should be monitored by an instrumented weir, flume, or other flow measuring device when the proposed rate of withdrawal is greater than 10 percent of the flow of the identified surface water feature at the time of the testing. If the proposed rate of withdrawal is less than 10 percent of the flow at the time of testing, then piezometers to assess changes in head may be utilized. Selection of the appropriate weir, flume, or other flow-measuring device, or methods should be based on the anticipated range of flows within the surface water feature and the proposed pumping rate. Flow measuring devices should be sufficiently accurate such that a 10 percent change in rate of flow should correspond to a change of at least 0.01 feet (approximately 1/8 inch).

All weirs and flumes should be constructed consistent with guidance outlined in *Groundwater and Wells* (Driscoll, 2nd edition, pages 541 to 546 and 1015 to 1020, or equivalent). To meet the Commission's flow accuracy requirements, the height of flow through v-notch weirs (for the most common v-notch weirs) should be at least 2.88 inches (0.24 feet). If rectangular weirs are used, the flow height through the notch should be at least 1.68 inches (0.14 feet). If the minimum height is not achieved with the installed equipment, the v-notch angle or width of the rectangular weir should be reduced prior to testing. Please note that the depths indicated in this paragraph refer to "H" as shown in *Groundwater and Wells* (Driscoll, 1986) and not the depth of the pool upstream of the weir. The Plan should include detailed specifications for the weir or flume construction (degree of v-notch, width of opening or dimensions of flume, etc.). Stage data should be recorded by a data logging pressure transducer installed in a stilling well at an appropriate location with respect to the design of the weir or flume. The level monitoring data should be converted to flow data for each flow-measuring device. Both level and flow data should be presented in graphical form in the hydrogeologic report. Appendix B contains suggested components for the final hydrogeologic report that a project sponsor submits with the groundwater withdrawal application following completion of the aquifer test and analyses of its results. For some projects, it may be appropriate to use a larger notch to collect background data than will be used during the constant rate phase of testing. However, sufficient time should be provided for the pool level upstream of the weir to equilibrate after changing the weir notch. The date and time of such changes should be recorded and provided with the hydrogeologic report.

If site conditions do not allow for the practical installation of flow measurement devices, the use of stream bank and stream bed piezometers to measure changes in head may be appropriate. In any of the monitoring scenarios, data logging pressure transducers should be used. For instance, surface water monitoring of ponds and wetlands (without flow), should use piezometers. The streambed or streambank piezometers should be in close hydraulic continuity with the coarse channel lag sediments, and be constructed with a sand-packed screened interval and functional seal to hydraulically separate the screen from the surface flow. An instrumented stilling well should be installed at an appropriate location proximal to the streambank or streambed piezometer to record stage data. Data collected from the piezometer and stilling well should be presented in graphical format in the hydrogeologic report and should be reported as elevation to asses head potential between the stream and the underlying channel sediments.

B. Water Chemistry

An aquifer testing plan should provide a narrative regarding the collection of water chemistry data during all phases of the aquifer test. Water chemistry can be important to help identify changing conditions within the aquifer and as a result of infiltration or capture of surface waters. This data should include temperature, conductivity, turbidity, and any other agreed-upon chemistry measurements, and should be collected from the well being tested at a minimum of every 2 hours during the constant-rate phase. Specifically, turbidity data is used in evaluating changes within the aquifer, including assessment of completeness of well development and if pumping of the well is causing additional development during the test. Additionally, temperature and conductivity should be collected from all surface water features (ponds, wetlands, streams, springs) being monitored at the start and end of each phase of testing, and every 24 hours during the constant-rate phase of testing. For piezometers, water quality from surface water proximal to the piezometer should be measured, if possible, to minimize disruptions to the water level monitoring in the piezometer.

The water quality monitoring data should be presented in the hydrogeologic report with descriptive text and linear scale graphs that show the plotted trends of each recorded parameter throughout the aquifer testing. In addition, any water quality data collected during the test to satisfy any additional permit requirements should be included in the hydrogeologic report.

C. Monitoring Equipment and Measurement Frequency

To ensure accurate and frequent collection of aquifer testing data, all monitoring locations should be equipped with data logging pressure transducers (data loggers), where possible, during all phases of testing. The data logger in the test well should record on a logarithmic schedule with maximum interval of one (1) minute for the constant rate and recovery phases of testing. The data logger in the test well should be reset to record on a logarithmic interval immediately prior to the start of the recovery phase of testing. Data loggers in observation wells should be programmed to record water level measurements at regular, constant intervals not to exceed 10 minutes during all phases of testing (see Table 1).

Table 1: Water Level Monitoring Frequency (transducer)

Monitoring Frequency		
Background	**Test**	**Recovery**
Test Well		
Once every 10 minutes	logarithmic, not to exceed 10 minutes	logarithmic, not to exceed 10 minutes
Other Surface water and Groundwater Monitoring Points		
Once every 10 minutes	Once every 10 minutes	Once every 10 minutes

As a check of accuracy and proper function, manual backup measurements at each observation location should be collected every 6 hours and once each hour from the test well to help prevent a failed test or a test having to be rerun due to equipment failure (Table 2).

Table 2: Backup Manual Water Level Monitoring Frequency*

Monitoring Frequency		
Background	**Test**	**Recovery**
Test Well		
Once every 24 hours	Once every 1 hour	Once every 24 hours
Other Surface water and Groundwater Monitoring Points		
Once every 24 hours	Once every 6 hours	Once every 24 hours

*Backup water level measurements are not required but are recommended to help avoid failed tests due to lost data.

The collection of manual measurements is not a requirement and should not be an impediment to obtaining access to a monitoring location, as property owners may object to manual measurements being collected at certain times of the day or night. Monitoring with other methods or frequencies may be acceptable but justification should be provided in the aquifer testing plan to support a deviation from the generally accepted practice of using data loggers.

For groundwater monitoring, the pressure transducers should be located deep enough to record the anticipated drawdown as a result of testing and operation of the well, but shallow enough to avoid vibration and turbulence-induced interference.

D. Precipitation Monitoring

Throughout all phases of an aquifer test, local precipitation data should be collected using on-site instrumentation. Although data logging precipitation monitoring systems are acceptable and recommended, they are not required. The on-site rain gage should be established in a location unaffected by trees, buildings, or other structures to obtain as accurate of a measure as possible. Snow fall should be recorded and reported in inches of snow as well as liquid equivalent. For aquifer tests conducted during the winter or when temperatures are near or below freezing, recording and reporting ambient air temperature should be considered and may be helpful in explaining water level or surface water flow fluctuations.

1. Precipitation totals should be recorded at a minimum of at least once every 12 hours throughout the constant-rate phase of testing. An attempt should be made to note the duration (start and stop times) of any precipitation events that occur during the aquifer testing.
2. Precipitation should be measured on-site during the background period, if possible. However, an internet available local rain gage may useful in assessing if conditions are likely conducive to starting the background period and can eliminate the need for travelling to the site to check the on-site rain gage to assess conditions.
3. On-site precipitation should continue to be measured through the recovery period. If precipitation occurs within 24-hours of the end of the constant-rate phase, attempts to record the start and end time of precipitation events should be made. After 24 hours, precipitation measurements can be collected at a decreased frequency.

II. Procedures for Aquifer Testing

This section provides information on the phases of a constant-rate test as well as general procedures needed to successfully complete each phase of testing. Please note that while these procedures apply to most aquifer tests, deviations from these procedures may be approved on a case-by-case basis. Projects requesting to significantly deviate from the standard aquifer testing procedures should provide justification for the proposed deviation within the Plan. The aquifer testing plan should clearly outline each of the constant-rate aquifer test phases below, including all proposed procedures.

An aquifer test is comprised of four phases or parts:

A. Step test;
B. Background Monitoring;
C. Constant-Rate Aquifer Test; and

D. Recovery Monitoring.

Please note that the step test can be completed either prior to or after the other phases of testing are completed. However, the background phase immediately precedes constant-rate phase, and the constant-rate phase immediately precedes the recovery phase. Each phase should transition to the next phase during testing.

A. Step Test

A step test is a short-term pumping test that involves operating a well for relatively short but consistent and defined durations or "steps" at a constant pumping rate and incrementally increasing the pumping rate with each step, until failure of the pumping rate is evident. Step tests are not required by the Commission, but the Commission recognizes the value of completing step tests and strongly encourages projects to complete step tests for new and existing wells. A step test provides information on the efficiency of the well over a wide range of pumping rates, the short-term maximum yield, may assist in characterization of the uppermost water-bearing zones, and assist in the selection of an appropriate rate for the constant-rate aquifer testing phase. If the proposed production well is to be used in a graphical distance-drawdown analysis, then a step test is necessary to provide data necessary to calculate the efficiency of the production well that is used in the analysis.

Step Test Procedures

If a step test is planned to be completed, procedures for the step test should be provided in the aquifer testing plan. General step test procedures are as follows:

1. Step tests are recommended to be completed at 25%, 50%, 75%, 100%, and 125% of the expected yield of the well. Incremental increases should be approximately the same (e.g., 25 gpm increase with each step).

2. Each step should be sufficiently long to eliminate borehole storage effects and be usable to graphically project water levels for each rate to 72-hours and 90-days to help assess the rate at which the constant rate test should be completed.

3. Although step tests may be completed during precipitation events, the results of the testing could be impacted by precipitation and may over-estimate final yield of the well. It is recommended that step tests also be performed during asymptotic recessional conditions.

4. The duration of the each step should be 1 to 2 hours and approximately the same.

5. It is recommended that select locations in the test monitoring network be operative during the step testing. These results can be used to evaluate the effectiveness of the monitoring network as well as identify potential impacts.

B. Background Monitoring

A period of 48 hours of background monitoring should be performed immediately preceding the start of the constant-rate phase. The purpose of the background monitoring is to establish pretest hydrologic conditions and trends (asymptotic groundwater or surface water recession). A pre-background recovery period is necessary in some situations including when the test well is an existing used well or is within the zone of influence of other operating wells. Pre-background recovery monitoring is described in section 2 below. All of the monitoring locations should be operative throughout the background monitoring period. The results are used to identify background interference (from other wells), and establish groundwater and surface water recession trends occurring during the constant-rate test. Documenting and recognizing pre-test trends is critical for evaluating observed changes at monitoring locations during remaining phases of testing. The forecast for potential precipitation should be considered prior to starting the 48-hour background period.

1. Consideration and Planning with Nearby Operating Wells

This section is intended to assist projects in developing operational plans that consider and plan for the impacts that existing nearby withdrawals may have on the test during all phases of testing. This section also assists projects in developing operational strategies to consider and allow for the continued operation of the project during testing activities. Although this section generally applies to existing projects, it may also be useful for new projects developing sources within or near the radius of influence for existing groundwater sources.

Aquifer testing of operating sources or proposed new sources within the area of influence of other operating sources may include a pre-background recovery period prior to background monitoring during which withdrawal(s) are discontinued and the test well is allowed to recover from normal operations of the well or nearby wells. The pre-background recovery period may be needed to allow the aquifer to recover so the background monitoring period can establish the requisite asymptotic recessional conditions conducive to aquifer testing. Aquifer testing plans for projects for which the pre-background recovery period is applicable should describe how the test well will be allowed to recover from normal system operations prior to initiating the background phase of testing. This should include an estimate of how quickly the aquifer recovers from normal operation and how the project will meet system demand during all phases of testing, including the pre-background recovery period, as recovery from normal operations may require a significant period of time.

Due to interference effects, projects testing a new or existing source should consider how the operation of nearby wells may impact the test and develop a plan to minimize impacts to aquifer test or data analysis. If other wells are expected to influence, or be influenced by, the test well, consideration should be given to ceasing operation of the nearby wells, or operating the nearby wells at a constant rate during all phases of testing. For existing projects, the Commission recognizes that total cessation of pumping or attaining ideal aquifer conditions prior to testing may not be possible and the project may need to propose options that maximize background recovery to minimize confounding or complicating operations, while meeting the needs of the system.

Commission staff is available for consultation to assist with development of appropriate operational plans. Member jurisdiction agencies may also have policy, guidance, or regulation regarding current operation of existing sources during testing. Please contact the appropriate member jurisdiction agency for additional guidance.

2. Background Monitoring Procedures

The Plan should adequately describe the procedures that will be followed during the background phase. Full descriptions of the frequency of groundwater level monitoring, surface water quality and level/flow monitoring; precipitation monitoring frequency and location (if different than during other phases); and how the aquifer will be evaluated for recessional asymptotic conditions should be included.

1. The aquifer should be 90 percent or more recovered from the step test, if conducted, prior to the start of the 48-hour background monitoring period.
2. At the end of the background period, all monitoring data should be assessed to document proper operation of the monitoring equipment throughout the background period and to confirm that asymptotic surface water and groundwater recessional conditions exist prior to starting the constant-rate phase of testing.
3. Field parameter measurements for water quality should be collected as outlined above in Monitoring Guidance – Water Quality. Water should be collected from surface water locations proximal to the surface water monitoring locations.
4. Frequency of groundwater and surface water level/ flow measurements should adhere to the standards above in Monitoring Guidance – Measurement Frequency (Table 1. Water Level Monitoring Frequency (transducer))
5. Collection of manual measurements should adhere to the standards above in Measurement Frequency (Table 2. Backup Water Level Monitoring Frequency) to confirm proper operation of the monitoring equipment and to serve as a backup if failure of the automated monitoring equipment occurs during the background period.

C. Constant-Rate Phase Aquifer Test

The constant-rate test phase provides data to evaluate the principle risk factors associated with a proposed withdrawal. The constant-rate aquifer test phase generally consists of pumping the proposed production well at a rate greater than or equal to the desired rate of withdrawal and observing the induced changes in groundwater levels, surface water bodies, and wetland hydrology. The duration of pumping should be sufficiently long to establish the hydrologic changes and trend characteristics to be able to predict the effects of the long term proposed production well operation. The generally recommended minimum duration of the constant-rate phase of aquifer testing is 72 hours. In limited circumstances, tests shorter than 72 hours may be acceptable, but sufficient justification should be provided to deviate from the standard and generally accepted practice.

The rate at which the constant-rate phase of testing should be performed is at the discretion of the project sponsor and its consultant. Generally, the rate should be determined through evaluation of the hydrogeologic setting and site conceptual site model, blown yield of the well, results of the step test, and the expected demand for the withdrawal. Although project sponsors provide an expected testing rate, Commission staff recognizes that the test rate may change based on the results of the step test, if completed. Accordingly, the Commission does not approve the test rate; rather, the Commission approves the procedures to be used during testing. The test rate can be changed without notification to, or approval by, the Commission.

<u>A constant-rate test may be completed at any rate desired; however, Commission staff will not recommend approval of a withdrawal that exceeds the tested rate.</u> The withdrawal rate requested in the groundwater withdrawal application may not exceed the test rate and a revised groundwater availability analysis should be prepared and submitted with the withdrawal application if the test rate, results, or requested withdrawal rate vary from the approved plan.

1. Constant Rate Test Procedures

The Plan should describe all of the procedures that will be implemented during testing to ensure adequate and accurate data collection. Because the Plan provides the procedures for testing, the entire Plan should be available for on-site personnel to review and confirm that the operation of the test conforms to the approved plan. Not conforming to the approved plan may result in a failed test and the need for retesting. If conditions are such that implementation of any aspect of the approved plan is not feasible, please contact Commission staff prior to initiating the test. **Commission staff should be notified at least 2 days prior to starting the constant-rate phase of testing.** Notice can be provided via email or telephone.

1. The constant-rate testing phase should be initiated only when the background data demonstrates asymptotic recessional trending or base flow conditions of groundwater and surface water immediately prior to the start-up of the constant-rate test. Base flow conditions should be expected through all phases of testing. Data collected during a constant-rate test phase when recessional or base flow surface water and groundwater level conditions have not been demonstrated with background monitoring data may result in a failed test. Commission staff is available to discuss background conditions and recessional conditions.

2. Aquifer tests should be performed on wells that are considered to be completed in their final constructed form and fully developed. Wells exhibiting incomplete development characteristics (i.e., turbidity spikes or unexplained water level fluctuations) may require an extension of the pumping phase or retesting. In carbonate, unconsolidated, or deeply weathered formations, continuous turbidity monitoring will be necessary, and the proposed monitoring methodology should be described in the aquifer test plan. Wells exhibiting incomplete development episodes during the testing should demonstrate development-free performance during the last 72 hours of testing.

3. During analysis of the testing data, maximum instantaneous withdrawal rate (MIWR) in gallons per minute (gpm), and consecutive 30-day average withdrawal rate in million gallons per day (mgd) will be evaluated. To afford projects operational flexibility for withdrawals, the desired MIWR may be higher than the 30-day average, but the 30-day average cannot exceed the MIWR multiplied by 1,440 minutes in a day. For operational flexibility, testing at a MIWR higher than the maximum 30-day average rate may be beneficial and acceptable, provided the test analysis is completed correctly.

4. Existing production wells with existing approvals to utilize water withdrawn from the well may discharge water into the water distribution system, provided all conditions of other permitting agencies are met. However, if system demand is not sufficient to utilize all of the water pumped during the test, a discharge location outside the area of influence may be needed. Discharge approvals may be required.

5. Discharge from the proposed production well should be routed such that recirculation does not impact testing, which typically results in a discharge point 300 to 500 feet down dip (bedding, schistosity, etc.) from the proposed pumping well and beyond the expected area of influence for testing. In karst-prone carbonate formations or certain other settings, an acceptable discharge location may be 2,000 feet or more from the test well. Recirculation affecting the test well or any monitoring location will invalidate the test and require retesting.

6. Prior to discharging test water from the proposed production well or the distribution system, the project sponsor must first obtain any required approvals from the appropriate state or local water management or other agencies. The approval(s) should be forwarded to the Commission prior to the start of testing. Any and all conditions of the discharge approval must be fully implemented during testing. If Commission staff inspects the test and suspects that a violation of the discharge approval is occurring, Commission staff will notify the project sponsor and the member jurisdiction agency of the potential violation.

7. The test flow rate (gallons per minute) and the cumulative flow (total gallons pumped) should be recorded at a minimum of once per hour. All flow rate adjustments should be documented with measurement of flow before and after adjustment, time of adjustment, rationale for the adjustment, and provided in the hydrogeologic report. The pumping rate of the production well should be monitored with an appropriate flow measurement device that is accurate to within 5 percent. The target flow rate should be established as soon as possible once pumping begins and should be held constant to within 5 percent of the target flow rate for the duration. Tests that fluctuate more than 5 percent or exhibit a declining pumping rate due to excessive drawdown or insufficient pump capacity will be considered a failed test.

8. The pump should be capable of maintaining the test rate throughout the entire test. Selection of the appropriate pump should consider effects of changing head developed as a result of decreased water levels in the well, increased levels in a storage tank, or system demand fluctuations that may affect pump performance. Deviation from the 5 percent standard provided above may result in a failed test. Staff recommends that operational testing of existing equipment be conducted prior to starting the testing to ensure that the pump installed in the well is sufficient to produce the test rate to within 5 percent for the duration of the test, including during changing conditions. A test with a declining pumping rate due to excessive drawdown or inadequate pump capacity will be considered a failed test and will require retesting. The pump and piping arrangement should include a check valve or similar device to prohibit water from flowing back into the well when the pump is turned off.

9. Water levels should be collected per the standards above in Monitoring Guidance – Measurement Frequency (Table 1. Water Level Monitoring Frequency (transducer)).

10. To verify the accuracy and proper function of the transducer(s) in the monitoring network, Commission staff recommends routinely collecting manual backup measurements at the frequency identified above in Monitoring Guidance – Measurement Frequency (Table 2. Backup Water Level Monitoring Frequency), and periodically comparing the manual backup data to the real-time water level monitoring data from the transducer in the test well. Any discrepancies that are identified during the test, between the automated water level data and the manual backup water level data, should be clearly documented and resolved in the field. Both the automated water level data and the manual backup water level data should be plotted on hydrographs and included in the hydrogeologic report. Any discrepancies between the manual and automated water level data, and all adjustments made to the transducer during the test, should be documented in the field notes, identified on the hydrographs, and described (timing and rationale for adjustment) in the text of the hydrogeologic report. Collection of manual backup data and verification of proper function may prevent a failed test due to equipment malfunction.

11. Field parameter measurements for water quality should be collected from the test well as outlined above in Monitoring Guidance – Water Quality.

12. Field parameter measurements for water quality should be collected from surface waters as outlined above in Monitoring Guidance – Water Quality.

13. Any change in the trend of the time-drawdown curve, such as might be caused by a positive/recharge boundary or negative/barrier boundary encountered during the test, should have a record of at least 24 hours. Therefore, any boundary condition encountered during the last 24 hours of pumping will require that the test be extended for at least 24 hours. The absence of 24 hours of test data following a trend change may result in failure of the test.

14. If a well exhibits unexpected excessive drawdown, testing should be suspended. The test rate should be re-evaluated and, after full recovery, the test should be restarted.

15. The project sponsor may be required, at its expense, to provide temporary water supply if aquifer testing results in interference with an existing water use.

16. In the Plan, the project sponsor should reference the Monitoring Guidance section regarding proper height and flow-through of weirs and ensure that the implemented aquifer test meets said standards

17. In the Plan, the project sponsor should reference Section V.A. – Monitoring Guidance regarding the accurate collection of stage data.

18. In the Plan, the project sponsor should reference Section V.A. – Monitoring Guidance regarding the accurate collection of local precipitation data. The amount

of precipitation that is acceptable during a test varies from one site to the next. Tests impacted by precipitation may need to be stopped, retested, or extended.

19. Periodically through the constant-rate phase of testing, the water level data should be graphed on a linear scale and semi-log scale and evaluated to identify potential boundary conditions, potential data collection errors, or procedural errors. Because certain issues can be corrected during the test, periodic downloads and plots of test well data and all other monitoring point data should be completed to analyze the data being collected and make corrections to collection methods or procedures, or monitoring equipment as needed. Periodic evaluation and appropriate corrections of methods or procedures or to monitoring equipment may avoid test failure.

20. Prior to stopping the constant-rate phase of testing, test data should be analyzed for potential boundary conditions or other conditions that may require that the constant-rate phase be extended.

D. Recovery Monitoring

The recovery monitoring allows confirmation of the constant-rate test results and aids in the evaluation of the potential impacts and the sustainability of the proposed withdrawal. The recovery monitoring immediately follows the constant-rate test and consists of monitoring the recovery of water levels and flow rates at all of the monitoring locations, following pump shutoff.

1. Recovery Monitoring Procedures

1. The minimum duration of the recovery monitoring is to be 24 hours and data collection should continue until groundwater levels have recovered to 90 percent of pretest levels, minus pre-test groundwater recession trend.
2. Water levels should be collected per the standards above in Monitoring Guidance – Measurement Frequency (Table 1. Water Level Monitoring Frequency).
3. Manual measurements should be collected per the standards above in Monitoring Guidance – Measurement Frequency (Table 2. Backup Water Level Monitoring). Frequency.