COUNTY OF MENDOCINO

COASTAL GROUNDWATER DEVELOPMENT GUIDELINES

Prepared For

Environmental Health

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Questa Engineering Corporation
PO Box 356; 1220 Brickyard Cove Road
Point Richmond, CA 94807

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COUNTY OF MENDOCINO

COASTAL GROUNDWATER DEVELOPMENT GUIDELINES

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INTRODUCTION

The County of Mendocino has adopted the following policies which apply to the development of new or expanded groundwater supplies in the coastal areas of the County. These policies and the attendant requirements for proof of water and hydrological studies are intended to assure that development is consistent with the limitations of the local water supply.

General Plan Water Policies

1. 6a

   No Development shall be allowed in the County beyond proof of the capability of the available water supply.

2. 6b

   No division of land or Use Permit shall be approved without proof of an adequate (as defined by the County Environmental Health Division) potable water supply for each parcel being created or proposed for special use.

3. 6c

   Existing water uses shall have priority over uses for new development. Appropriate planning actions for water resources shall be taken after notification and input from neighborhood residents.

Coastal Element (LCP) Water Policies

1. 3.8-9

   Approval of the creation of any new parcel shall be contingent upon an adequate water supply during dry summer months which will accommodate the proposed parcels, and will not adversely affect the groundwater table of contiguous or surrounding areas. Demonstration of the proof of water supply shall be made in accordance with policies found in the Mendocino Coastal Groundwater Study dated June 1982, as revised from time to time, and the Mendocino County Environmental Health Divisions's "Land Division Requirements" as revised (**Appendix 6**).

   Commercial developments and other potential major water users that could adversely affect existing surface or groundwater supplies shall be required to show proof of an adequate water supply, and evidence that the proposed use shall not adversely affect contiguous or surrounding water sources/supplies. Such required proof shall be demonstrated prior to approval of the proposed use.

2. 3.8-10

   In order to be developed to the smaller parcel size, areas indicated on the map as having a variable density zoning classification shall be required to be served by a public water system which utilizes surface waters, and which does not impact upon the groundwater resources, or by completion of a hydrological study which supports those greater densities.

Mendocino Town Plan Water Policies

1. 4.13-16

   All new development shall be contingent upon proof of an adequate water supply during dry summer months which will accommodate the proposed development and will not deplete the groundwater table of contiguous or surrounding uses. The findings of the Coastal Ground Water Study of June 1982 shall be incorporated in the Town of Mendocino Plan.

   The accompanying guidelines outline the minimum requirements and procedures for testing, analysis and reporting of groundwater information to comply with the above water policies. The recommended methodologies are generally applicable to cover all cases. Alternative or more extensive investigative approaches may be warranted and should be considered on a case-by-case basis.

GENERAL STUDY REQUIREMENTS

The required levels of investigation for groundwater development are listed in **Table 1**. The requirements vary depending upon proposed project type, location and lot size; and incorporate the recommendations contained in the 1982 Mendocino County Coastal Groundwater Study (DWR, 1982).

- No groundwater investigation for water supply is required for individual residences on existing lots of record, except in the Town of Mendocino, where all new development and land use changes require hydrological studies. The only exceptions to the hydrological study requirements in the Town of Mendocino are cases where a change in land use can be demonstrated to result in no anticipated increase in water use.

- Groundwater study requirements for creation of minor and major subdivisions and second residential units may range from no investigation to a complete hydrological study, depending upon lot size (i.e., dwelling density) and the respective DWR groundwater resource classification for the project area.

- All major subdivisions which propose to develop and use a public water system are required to conduct a hydrological study.

- Commercial, institutional and industrial facilities are required to conduct either Proof of Water or hydrological studies, depending upon the water resource classification, parcel size, adjoining parcel sizes, and the water demands of the facility. The Mendocino County Environmental Health Division may waive the testing requirements on a case-by-case basis for very low water use operations, or where a change in land use can be demonstrated to result in no anticipated increase in water use. Conversely, the Environmental Health Division may increase the testing requirements for “minor” water use facilities in areas of marginal or critical water resources.

General study requirements are recommended by the Mendocino County Environmental Health Division to the Planning Commission or Board of Supervisors as a Conditions of Approval for a proposed project. The guidelines provided in this document outline, in general, the required testing and evaluation methods. In special circumstances, due possibly to the size, nature or location of a particular project, the Planning Commission, Board of Supervisors or the California Coastal Commission may require more extensive groundwater investigation in addition to or in place of the requirements outlined in these guidelines.

TABLE 1

GROUNDWATER INVESTIGATION REQUIREMENTS
FOR LAND DEVELOPMENT

Project Type	DWR[1] Classification	Dwelling Density (Acres/D.U.)	No Investigation Necessary	Proof of Water	Hydrological Study[2]
		Coastal Zone Excluding Town of Mendocino			
Single Family Residences on Existing Lots of Record	All	All	X		
Minor and Major Subdivisions and 2nd Residential Units	SWR	<2		X	
		≥2	X		
	MWR	<2			X
		<5		X	
		≥5	X		
	CWR	<5			X
		≥5		X	
	CWR br	2-20		X	
		≥20	X		
Major Subdivision w/Public Water System	ALL	ALL			X

TABLE 1 (CONT'D.)

GROUNDWATER INVESTIGATION REQUIREMENTS
FOR LAND DEVELOPMENT

Project Type	DWR[1] Classification	Dwelling Density (Acres/D.U.)	No Investigation Necessary	Proof of Water	Hydrological Study[2]
Commercial, Institutional And Industrial					
• Major Water Use[3]	ALL	ALL			X
• Minor Water Use[4]	ALL	ALL		X	
Town of Mendocino					
All Land Use Changes & Developments	CWR	ALL			X[4]

1 SWR Sufficient Water Resources
MWR Marginal Water Resources
CWR Critical Water Resources
CWR br Critical Water Resources (Bedrock)

2 Proof of Water is understood to be part of the hydrological study.

3 "Major water use" is generally defined as equal to or greater than 1500 gal/day maximum demand; the Mendocino County Health Department may, on a case-by-case basis, require hydrological studies for lower water use facilities in areas of marginal (MWR) or critical (CWR) water resources.

4 Exception may be granted on a case-by-case basis where no increase in water use can be demonstrated.

WATER WELL TESTING GUIDELINES FOR PROOF OF WATER

Objectives

Water wells along the Mendocino Coast intercept groundwater in terrace and alluvial deposits and in fractured bedrock. Hydraulic conductivity can vary by several orders of magnitude between the various geologic materials encountered; thus, water well testing must be carefully planned and conducted to provide accurate and reliable data for analysis of water supply potential.

The specific objective of water well testing is to demonstrate that the pumped well has sufficient yield to meet maximum daily water demands. Possible water table drawdown effects on adjoining properties are considered to be adequately mitigated if the minimum lot size criteria recommended in the 1982 Mendocino Coastal Groundwater Study are adhered to.

Professional Qualifications

Water well testing for Proof of Water requires background and understanding of the principles of groundwater hydrology. Testing must be conducted by a Registered Geologist, a Certified Engineering Geologist, a Registered Civil Engineer, a qualified Registered Sanitarian, or by an experienced technician under the supervision of one of the above.

Pump Testing Requirements

Proof of Water shall be established by conducting a pump test(s) and comparing well yield, observed during pump testing, to the estimated water demand for the property.

Water wells shall be tested during dry season conditions, which are defined to be the period of August 20th to October 31st.

Estimated Water Demand

The estimated water demand shall be determined for individual projects as follows:

1. Single Family Residences

Water Requirements for single family residences along the Mendocino Coast are estimated to be 180 gal/day per capita (DWR, 1982), or 540 gal/day per dwelling unit. Assuming a 2.5 peaking factor for maximum day demand, the minimum required water supply for individual residence should be 1.0 gal/min.

A minimum supply of 0.5 to 1.0 gal/min. may be acceptable for individual residences if supplemented with water storage capacity of 2,500 gallons or more. In no case will a supply of less than 0.5 gal/min. be considered acceptable for individual residences.

2. Commercial, Institutional and Industrial Facilities

Water requirements for commercial, institutional and industrial facilities shall be determined individually for each project, based upon usage rates for comparable facilities along the North Coast of California, and consideration of standards of practice for water supply planning and engineering. The data, references or rationales for water use estimates for each project shall be clearly stated in the Proof of Water report.

Pump Testing Methods

A constant rate test shall be required in all cases to establish well yield. In certain areas, it is recommended that a step drawdown test also be conducted prior to the constant rate test to assist in determining the optimum pumping rate. The two methods of pump testing and their applicability are briefly described below.

1. Constant Rate Test

Constant rate pump tests are conducted at a pre-determined discharge rate which is held constant over the duration of the constant rate test. This test is applicable for testing wells in terrace or alluvial deposits or wells which penetrate aquifer materials which have reasonably uniform horizontal hydraulic conductivities.

2. Step Drawdown Tests

Step drawdown tests are conducted by incrementally increasing the pump discharge rate in steps, which should be equal in time. The pump rate is held constant during each step and increased for each successive step without stopping the pump. This allows a range of specific capacity rates (discharge/drawdown) to be calculated, and an optimum pumping rate to be estimated. The optimum rate is then used in a constant rate test to be conducted following the step drawdown test. Step drawdown tests are applicable for wells which penetrate aquifer materials having a high degree of variability in hydraulic conductivity; they are specifically recommended for wells which have screened sections which extend into terrace/alluvial deposits and fractured bedrock, sometimes referred to as “composite” wells.

Pump Test Procedures-Constant Rate

1. Pre-Pump Test

Following installation and development of the supply well, and prior to the commencement of the pump test, a short-term bail and recovery test should be conducted to provide an estimate of well yield. The recovery data can be used to calculate the horizontal hydraulic conductivity and to select an optimum pumping rate for the constant rate test. Appropriate formulas for calculating hydraulic conductivity from field tests may be found in Freeze and Cherry (1979) and Luthin (1973), among others.

2. Casing Storage

The amount of water stored in the well casing above the pump setting should be calculated for use subsequently in determination of pump test duration.

3. Test Duration

Duration of the pump test should be a minimum of three log cycles, expressed in minutes (approximately 17 hours), or until drawdown stabilizes, whichever is greater. This should be in addition to the time required to pump the calculated casing storage above the pump setting.

4. Water Level Measurements

Water level measurements in the pumped well should be made at regular intervals, ten times per log cycle, throughout the pump test. Measurements are to be accurate within ‘0.1-foot (or 1-inch).

5. Discharge Rate

The pump discharge rate is to be monitored and maintained to within 10% of the selected pump test rate. The pumpage rate should be measured at least twice per log cycle.

6. Water Table Recovery

Recovery of the water table, after pumping, should be monitored until the water table has recovered 80% of total drawdown. Water level measurements should be made at the intervals and to the same level of precision as during pumping (10 per log cycle expressed in minutes).

7. Disposition of Pumped Water

Water pumped from the well during testing shall be conserved by storage or routing to a recharge/discharge area which is beyond the influence of the pump test.

<u>Pump Test Procedures – Step Drawdown</u>

Procedures for the constant rate pump test shall apply with the following exceptions:

1. Test Duration

The step drawdown test should be conducted for a period sufficient to determine the specific capacity of the aquifer at each step. Normally each step should be run until the drawdown at the pumped well stabilizes. All steps should be equal in duration. The number of steps to be run is left to the judgment of the professional conducting the test. A 12 to 24 hour step drawdown test is generally sufficient to test unconfined aquifers, as in most coastal terrace deposits.

2. Constant Rate Confirmation

Following the completion of the step drawdown test, or when maximum drawdown is achieved, a constant rate test is needed to confirm the optimum well yield. An optimal pump rate based upon the specific capacity characteristics should be selected for the constant rate test. This test should be conducted in accordance with procedures previously specified for constant rate tests.

Analysis of Data

The observed maximum sustained yield of the well as determined from the pump test should be equal or exceed the estimated maximum daily water demand to establish Proof of Water. In some cases the specific capacity of the well (discharge/drawdown) may be utilized to justify a higher well yield. Such an approach should be considered only for special circumstances; and the supporting analysis must be based upon careful review of a number of factors, including the saturated thickness of the aquifer, hydraulic conductivity, pump setting, drawdown effects, etc.

Report of Findings

A Proof of Water shall be prepared and submitted to the Mendocino County Environmental Health Division documenting the field studies, estimates of water demand and analysis and conclusions of pump testing and well yield determinations. The report, at a minimum, should include:

- Project description;
- Location and site maps;
- Well logs;
- Pump test data and description of procedures;
- Calculations of water demand, well casing volume, specific capacity, well yield and drawdown;
- Conclusions and recommendations;
- Supporting references; and,
- Field data sheets

HYDROLOGICAL STUDY GUIDELINES

General

Hydrological studies are required for certain types of development and land divisions in Mendocino County in order to determine the adequacy of on-site groundwater supply for proposed development and to document any adverse impacts on local water users and the aquifer as a whole.

Hydrological studies are required for the following developments:

- All minor and major subdivisions and second residential units proposed for development at densities greater than those recommended in the 1982 DWR "Mendocino County Coastal Ground Water Study" and **Table 1;**

- All major subdivisions proposing to establish a new or expand an existing public water system;

- All subdivisions having dual zoning designations, in which the higher permitted development density is proposed;

- All commercial, institutional and industrial developments having estimated maximum day water use of 1500 gal/day or more; and,

- All new or expanded development in the Town of Mendocino, except for cases where no anticipated increase in water use is demonstrated.

Professional Qualifications

Hydrological studies should be conducted by a Registered Geologist, a Certified Engineering Geologist, or a Registered Civil Engineer with a minimum of five (5) years of experience in groundwater hydrology.

Elements of Hydrological Study

The hydrological study should include consideration of local geology and hydrology, documentation of current groundwater development, estimation of water use by the development, a pump test, assessment of the on-site availability of groundwater, and analysis of potential impacts of the proposed groundwater development. The hydrological study should be documented in a report summarizing the information and analyses, and should include appendices containing supporting data. The following report outline is suggested:

- Introduction
- Estimated Water Demand
- Hydrological Setting
- Performance of Pump Test
- Analysis

- Conclusions
- Appendices

Introduction

The introduction should cite the need for the study, describe the development or land division, and provide location maps. Included should be:

- Description of the development type and parcel size; and,

- Location of the development with respect to other properties and local wells; use of U.S. Geological Survey topographic maps and assessor's parcel maps is recommended.

Estimated Water Demand

The expected water demand for the project shall be estimated, including assumptions used in the estimate. If more than one interpretation is possible, then the higher use value should be applied. The following guidelines should be adhered to for estimating water demand.

1. **Single Family Residences**

   Water requirements for single family residences along the Mendocino Coast are estimated to be 180 gal/day per capita (DWR, 1982), or 540 gal/day per dwelling unit. Assuming a 2.5 peaking factor for maximum day demand, the minimum required water supply for an individual residence should be 1.0 gal/min. A minimum supply of 0.5 to 1.0 gal/min. may be acceptable for individual residences if supplemented with water storage capacity of 2,500 gallons or more. In no case will a supply of less than 0.5 gal/min. be considered acceptable for individual residences.

2. **Commercial, Institutional and Industrial Facilities**

   Water requirements for commercial, institutional and industrial facilities shall be determined individually for each project, based upon usage rates for comparable facilities along the North Coast of California, and consideration of standards of practice for water supply planning and engineering. The data, references or rationale for water estimates for each project shall be clearly stated in the report.

3. **Public Water Systems**

   Water requirements for public systems shall be determined in accordance with criteria established in "California Water Works Standards", or as may be justified by documented usage rates for similar developments and areas.

Hydrological Setting

A summary of the local hydrological setting, site characteristics, and present groundwater uses should be provided. This should address the following:

1. Local Geology and Groundwater

Describe the local geology and occurrence of groundwater. Identify nearby streams. Locate all springs with measurable flow within 300 feet of the parcel; and measure or estimate flow conditions during the dry period of the year. Use of available reports by the California

Department of Water Resources, (DWR), the State Water Resources Control Board-Division of Water rights, and other is recommended.

2. Aquifer Description

Identify the aquifer to be developed. For terrace aquifers, note the extent of the aquifer, average thickness, and average storage capacity. For example see DWR, June 1982, cross-sections and summary tables.

3. On-Site Hydrogeologic Conditions

Document on-site hydrological conditions, including geologic materials encountered during drilling of the well, and static depth to water during the August 20th to October 31st test period. DWR Water Well Drillers Report of the well should be included.

4. Existing Wells

Identify all wells within 300 feet of the parcel under study. Show well locations on the assessors parcel map or with measured distances to the pumping well. Describe each well, including depth, pump setting, and perforated interval, geological log if available, use and estimated pumpage, and water level fluctuations. Geologic cross-sections illustrating information from available well logs are recommended.

<u>Performance of Pump Test</u>

The pump test is intended to document that adequate groundwater is available on site for the proposed project ("Proof of Water") and to determine any adverse impacts on local groundwater users and the aquifer as a whole. Pump testing requirements for hydrological studies are as follows:

1. Notification

All property owners within ¼ mile of the pumped well should be notified of the date, time, location and purpose of the pump test, and should be provided with a contact name, phone number and address in the event that their well(s) apparently are affected by the test. The Mendocino Community Services District should be notified of any pump tests to be conducted in the Town of Mendocino. The notice should emphasize that it is important for neighboring well owners to respond as soon as any effects on their well are observed. Subsequent letters and written responses to the letters should be submitted with the hydrological study report. If, during pumping, there is evidence that an adjoining property well(s) is being seriously depleted, the pump test should be interrupted until the situation can be investigated and resolved.

2. Pump Test Methods

Pump testing shall be conducted generally in accordance with the procedures outlined in the preceding section entitled “Water Well Testing Guidelines for Proof of Water”. The guidelines provide for the performance of a constant rate test and/or step drawdown test depending upon the uniformity of aquifer characteristics over the screened interval of the well.

In regard to pump test duration, the following shall apply for hydrological studies.

- For individual on-site groundwater development for Minor or Major Subdivisions and Second Residential Units, pump test duration for hydrological studies shall be a minimum of 17 hours or until water levels in the test well and monitoring wells stabilize, whichever is greater.

- For Public Water Systems and Major Water Use Projects (per Table 1), minimum pump test duration for hydrological studies shall be defined by the prevailing geological conditions as follows:

  - Alluvial Deposit Wells - 17 Hours
  - Terrace Deposit Wells - 24 Hours
  - Bedrock Wells - 72 Hours

  In the case of composite wells, i.e., those penetrating both terrace deposits and underlying bedrock, the minimum required pump test duration shall be determined as follows:

  4. 24 Hours – if the water level in the pumped well remains at or above the bedrock contact throughout the test; and,

  5. 72 Hours – if the water level in the pumped well recedes and remains below the bedrock contact during the test.

  Since most coastal wells are terrace deposit and/or bedrock wells, pump test procedures for alluvial deposit wells must be approved by the Environmental Health Division prior to initiating the test.

- Pump test duration for all hydrological studies performed in the Town of Mendocino shall be a minimum of 72 hours.

3. Monitoring Well(s)

In addition to the procedure outlined for Proof of Water, pump testing for hydrological studies shall include water level observations in at least one monitoring well throughout the pumping period.

It is recommended that at least one monitoring well be installed within the zone of influence of the pumped well specifically for use in the pump test. As an alternative, existing nearby water wells may be suitable as monitoring wells, provided: (a) they have a screened interval which intersects the same aquifer as the well to be tested; and, (b) they are not pumped during the test.

If a monitoring well is installed specifically for the pump test, care should be taken to assure that the screened interval of the monitoring well intersects the aquifer from which the pumped well draws water.

A 24-hour pre-test monitoring of water levels in the well to be pumped and in any monitoring wells is recommended. A 4-hour interval between readings is suggested, unless conditions warrant more or less frequent readings. The pre-test monitoring is used to establish any background influences on groundwater levels, i.e., from other pumping activities.

Throughout the full duration of the pump test and recovery period, water level measurements in the monitoring well(s) should be made at regular intervals, similar to readings taken for the pumped wells. Measurements are to be accurate within '0.1' foot (or 1 inch).

Data Analysis

An analysis should be provided of the pump test results and other information in order to document proof of water and to determine impacts on local water users and the regional aquifer.

1. Well and Aquifer Characteristics

The following calculations and data should be provided from field measurements to characterize the pumped well and local aquifer.

- Drawdown and Recovery. Plot water table drawdown and recovery curves on log paper for both the pumped well and monitoring well(s). The curves should be presented for easy comparison. Tabulate all time, water level, and pump rate data in an appendix.

- Transmissivity and Storage. Compute transmissivity and storage coefficient for the local aquifer using the Theis equation, Cooper-Jacobs method (Todd, 1980) or other appropriate techniques. Document methodology, including equations and assumptions, and interpretations.

  Note: The use of a step drawdown pump test will ordinarily preclude the use of standard distance-drawdown and time-drawdown graphical analyses, as well as the use of Theis and Cooper-Jacobs equations, for calculation of trasnmissivities and storage coefficients. However, by allowing water levels to recover completely before conducting the constant rate test (to confirm well yield), these standard techniques can be used. Several other methods of calculating trasnmissivities and storage coefficients can be used when conducting a constant rate test sequentially with a step drawdown test; and some of these are provided at the end of Appendix A.

- Well Efficiency. Compute well efficiency (Todd, 1980).

- Specific Capacity. Compute the specific capacity of the well. This is defined as the discharge per unit of water table drawdown.

2. Proof of Water

The observed maximum sustained yield of the well as determined from the pump test should equal or exceed the estimated maximum daily water demand to establish Proof of Water. In some cases the specific capacity of the well (discharge/drawdown) may be utilized to justify a higher well yield. Such analysis must be based upon consideration of a number of factors, including, the saturated thickness of the aquifer, hydraulic conductivity, pump setting, drawdown effects, etc.

3. Water Table Effects

The observed and computed drawdown at neighboring wells or installed monitoring wells will provide the basis for assessing the extent of adverse effects on the water table and groundwater supplies on surrounding properties.

- Evaluation Criteria. An adverse effect of the water table surrounding properties shall be considered to occur if pumping at the maximum day demand at the pumped well results in a water table drawdown at wells on adjoining properties which either:

  a) amount to more than 10 percent of the existing drawdown at such wells under conditions of maximum day pumping demand; or,

  b) causes a decline (estimated or observed) in the existing well yield to a level which is less than 90 percent of maximum day water demand for the adjoining property.

  If either situation is estimated or found to occur, mitigation measures will be required.

  The water table drawdown at the adjoining well and the test well under maximum day pumping rates shall be estimated on the basis of:

6. Specific capacity for the pumped well being tested; or,

7. Pump test documentation supplied by the adjoining well owner for the well in question.

  This analysis assumes that adjoining wells operate under similar hydrogeologic conditions and physical characteristics as the pumped well, unless evidence to the contrary is available.

  If more than one well is proposed it must be demonstrated by calculations, or by actual pump testing, that the cumulative drawdown effect from all wells will be less than 10 percent of the maximum day drawdown at adjoining well that may be affected.

- Pump Test Results. Water table drawdown at all wells within the pumping depression or within 300 feet of the pumped well shall be reported or computed for conditions during pump testing. Various procedures for computing drawdown and the zone of influence of pumping well are provided in Appendix A. The drawdown should be related to the screened interval and total depth of each well, if known.

- Projected Drawdown. The projected drawdown effect on the water table and adjoining wells should also be estimated for the following conditions:

8. maximum day water demand (if different from pump test rate);
9. average water demand; and,
10. dry year water table conditions (estimated from background groundwater monitoring data or water balance determinations).

4. Regional Impact

To evaluate the regional impact, the expected annual pumpage of the well in acre-feet should be computed. If the well taps a terrace aquifer, compare the annual well pumpage amount to the storage capacity of the local aquifer and annual recharge as estimated from water balance calculations. This evaluation is to be provided for information purposes to expand and refine the groundwater database for the Mendocino Coastal areas; there are no specific criteria for approval or denial of a project based on potential regional groundwater impacts.

In cases where local springs may be affected by the proposed groundwater development, the estimated impact on spring flow and downstream users should be evaluated. Also, documented spring flow from terrace aquifers should be accounted for to establish the aquifer discharge and possible surplus water during dry season conditions.

5. Mitigation Measures

Mitigation measures normally considered to reduce water table effects on adjoining properties to acceptable levels include:

- Reduced water usage and pumping rates by means of water conservation or reduced project size;
- Alternate or multiple well installations; and,
- Increased storage capacity to minimize peak pumping demand.

Other measures may be considered on a case-by-case basis.

Conclusions

Conclusions should include: (1) comparison of the estimated water demand and well capacity to establish proof of water; (2) summary of impacts on local wells; and, (3) comparison of annual well pumpage and storage capacity of the aquifer to assess the impact of the well on available groundwater supply.

Appendices

Appendices should include all relevant pump test data and well logs, as well as letters or other communications from nearby well owners, and written responses.

GUIDELINES FOR REVIEW OF PROOF OF WATER AND HYDROLOGICAL STUDIES

General

The County should retain an experienced hydrologist or hydro-geologist to review proof of water reports and hydrological studies. A list of useful technical references is attached.

Introduction

Each hydrological study should locate the sit eon both assessor's parcel maps and topographic maps. The latter maps allow location of the site and well according to the township and range grid system. It is recommended that hydrological studies be filed according to location, or that an index based on location be maintained.

Estimated Water Demand

Information on per capita water demand in the North Coast region is available in two reports by the California Department of Water Resources (DWR), "Mendocino County Coastal Ground Water Study" (June 1982), and "Town of Mendocino Ground Water Study" (June 1985).

Also see DWR Bulletins #166-3 and #198-84, respectively, "Urban Water Use in California" and "Water Conservation in California." Bond and Straub (1972) also report water supply requirements for different commercial and industrial firms.

Hydrological Setting

Major references regarding hydrological conditions in Mendocino County are included in the two reports by DWR cited above. The first report divides the coastal area into geographical subunits. Information on geology, the occurrence of groundwater, and well locations is presented for each. Cross-sections also are included. Major subunits are divided further into terrace aquifers; data on aquifer thickness, areal extent and storage capacity are presented in tables.

The major sources of information regarding on-site conditions are driller's logs for the pumping well and nearby wells. Such logs describe geologic materials encountered in drilling the well, construction of the well including boring and casing diameters, sanitary seal, casing type, perforated interval, and pump or bail test information.

Driller's logs or equivalent information should be provided for both the pumping well and observation well(s). The pumping well and observation well(s) should be similar in terms of geology and screened interval, so that the pumping test results accurately reflect local aquifer conditions. If no existing well is appropriate, then an observation well should be drilled. A pumping test using an appropriate observation well provides reliable information on the drawdown cone which can be used to assess impacts on wells within that cone.

Performance and Analysis of Pumping Test

Guidelines for the pumping test are intended to result in relatively brief, but professionally conducted tests that produce reliable data. The guidelines are specific about the tasks to be included in the pumping test and the accuracy of measurements. Nevertheless, hydrogeologic conditions in Mendocino County are variable and pumping test analyses always are subject to some interpretation. Accordingly, the report of the pumping test should be reviewed by an experienced groundwater hydrologist.

Proof of Water

The comparison of the estimated water demand and maximum sustained well yield observed during pumping is the basis for "proof of water." The computed specific capacity of the well (discharge/drawdown) provides another measure of the productivity of the well.

Impacts on Local Water Table and Users

The hydrological study should contain specific assessments of the impacts of pumpage on all wells within the drawdown cone or within 300 feet, whichever is greater. Letters from local well owners responding to the notice of the pump test also should be considered; these letters could reveal the existence of affected wells that were overlooked. The pump test procedures also provide for interruption of pumping if an immediate and serious drawdown effect is noted on adjoining property wells. The situation should be resolved before resuming the test.

The recommended criterion for judging adverse water table drawdown or impact at adjoining wells 10 percent of the existing drawdown under maximum day pumping rates or reduction of well yield to less than 90 percent of maximum day demand. For an adjoining well which just meets the minimum well yield requirement of 1.0 gpm, a 10 percent drawdown of the water table would reduce the well yield by an equivalent 10 percent, to 0.9 gpm. This is a measurable effect, but generally acceptable considering that average water usage should by only about 40 percent of maximum day pumping rates. Also, it can be generally assumed in terrace aquifer situations that the adjoining property will have an equivalent drawdown effect on the new well being tested, under similar pumpage and water usage rates. Larger production wells for commercial/industrial operations or public water systems would have a more pronounced effect on adjoining individual supply wells; however, the 10 percent criterion remains a reasonable basis for judging the significance of water table effects without unduly restricting the development of new groundwater supplies. Mitigation of impacts on the water table and existing supplies may be necessary where the projected drawdown of the water table is excessive under maximum day pumpage requirements. Alternative mitigation measures might include:

- Reduced water usage and pumping rates by means of water conservation or reduced project size;
- Alternate or multiple well installations; and,
- Increased storage capacity to minimize peak pumping demand.

Regional Impacts

The assessment of regional groundwater impacts is viewed as a long-term responsibility of the County. Data and analyses supplied in the hydrological studies should be used to expand and refine the database available to the County for regional impact considerations.

In order to assess the impact of pumpage on regional aquifers, the County should, from time to time, determine the number of wells tapping each terrace aquifer, estimate current usage of the storage capacity of each terrace aquifer (see DWR reports), and maintain a tally of usage of storage capacity as new groundwater pumpage is approved.

In critical water areas this periodic analysis of groundwater pumpage may also be extended to consider the potential water needs of future projects. Special studies may need to be commissioned from time-to-time by the County to evaluate the cumulative impact of existing and reasonably anticipated future projects. In this regard, "cumulative impact" means two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts. The individual effects may be changes resulting from a single project or a number of separate projects. The cumulative impact from several projects is the change in the environment which results from the incremental impact of the project when added to other closely related past, present and reasonable foreseeable provable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time.

Assessment of regional groundwater impacts is generally not recommended to be based on estimation of perennial yield (safe yield) for the following reasons:

- Accurate estimation of perennial yield is a complex task requiring extensive hydrologic information. Such information generally is lacking for the numerous small groundwater units of the Mendocino Coast.

- The perennial yield of a groundwater basin depends not only on hydrology, but on management (Todd 1980). A basin can be managed to optimize groundwater yield. For example, yield can be increased through well siting that induces recharge from stream channels or prevents groundwater outflow from springs. Yield also can be increased through artificial recharge.

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APPENDIX A

ANALYTICAL METHODS FOR ASSESSING

AQUIFER CHARACTERISTICS

The following equations and associated assumptions are offered as examples of methods of interpreting aquifer drawdown characteristics. The application of these methods to pump tests conducted on the Mendocino County Coast will be at the judgment of the professional conducting the investigation.

THIEM EQUATION

Application: For wells which achieve drawdown equilibrium during pump testing. Data from a constant rate pump test and from observation wells within the pumped well's radius of influence are required for interpretation using this method.

Calculations:

1. Hydraulic Conductivity:

$$K = \frac{1055\ Q \log r_2/r_1}{(h_2^2 - h_1^2)}$$

Where:

K = Hydraulic conductivity (gpd/ft^2)

Q = Pump discharge (gpm)

r_2 = Distance to farthest observation well (ft)

r_1 = Distance to nearest observation well (ft)

h_2 = Saturated thickness of aquifer in farthest observation well (ft)

h_1 = Saturated thickness of aquifer in nearest observation well (ft)

2. Radius of Influence

The Thiem equation can be modified to calculate the radius of influence and the drawdown at any distance within the calculated zone of influence. Only on observation well is required. These equations can be used to estimate the unknown parameter when using data taken following stabilization of the drawdown cone.

$$R = 10 \exp \left(\log r_1 + \frac{K\,(b^2 - h^2)}{1055Q} \right)$$

Where:
- R = Radius of influence (ft)
- K = Hydraulic conductivity (gpd/ft^2)
- Q = Discharge rate (gpm)
- b = Saturated thickness of aquifer (ft)
- r_1 = Distance to observation well (ft)
- h = Saturated thickness at the observation well (ft)

(Note: $h = b$ – drawdown in observation well.)

3. Drawdown at Any Point Within the Radius of Influence:

$$s = B - (1/k\ [1055Q\ (\log r_2/r_1)] + [b - s_1]^2)^{1/2}$$

Where:
- s = Drawdown at distance r_2 (ft)
- s_1 = Drawdown at observation well r_1 (ft)
- r_1 = Distance to observation well r_1 (ft)
- r_2 = Distance to point within radius of influence.

<u>Assumptions:</u>

- Aquifer has uniform hydraulic conductivity within the radius of influence of well;
- Well fully penetrates the aquifer and saturated thickness is constant, before the start of pumping;
- Well is 100 percent efficient;
- Aquifer is not stratified;

- Water table gradient is zero;
- Laminar flow exists throughout the aquifer;
- Pump discharge is constant; and,
- Cone of depression reaches equilibrium; i.e., the aquifer recharges the well at the same rate as the pump discharges water.

  (Note: It is unlikely that any or all assumptions will be completely satisfied by wells installed in the real world. However, pump test data provides average values for some parameters and other conditions exist such that the assumptions may be satisfactorily approximated. Thus, these equations can be used to estimate or approximate the unknown parameter.)

THEIS NON-EQUILBIRIUM EQUATION

Application: For predicting drawdown at any point within the radius of influence. Equilibrium is not required to apply this method. One observation well is required.

Calculations:

The use of the Theis equation requires matching the drawdown curve with a type curve. W(u) and 1/u values are determined from the curve matching. Transmissivity and storage coefficients can then be calculated using these formulas:

$$T = \frac{114.6\ Q\ W(u)}{d}$$

$$S = \frac{u\ T\ t}{1.87r^2}$$

Where:
- r = Distance to observation well (ft)
- W(u) = Well function of u
- d = Drawdown at an observation well within the zone of influence (ft)
- T = Transmissivity in (gpd/ft)
- t = Time at match point (days)
- S = Storage coefficient
- Q = Discharge rate (gpm)

The resulting T and S values can be used to calculate u for any point using:

$$u = \frac{1.87r^2 1^S}{T\ t}$$

Followed by:

$$s = \frac{114.Q\ W(u)}{T}$$

Where: W(u) = Is determined from u using Table 2.

s = Drawdown at any point within the radius of influence

r = Distance to point of measurement (ft)

t = Time elapsed from start of test (days)

<u>Assumptions:</u>

The Theis equation uses similar assumptions as listed for the Theim equation except that the cone of depression need not be at equilibrium.

COOPER-JACOBS NON-EQUILIBRIUM EQUATION

For values of u less than 0.001 (small r, large t), the Theis non-equilibrium equation can be modified to:

$$\Delta s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2\ S}$$

Thus a plot of drawdown, s, versus the log t will yield a straight line. Drawdown data is taken at an observation well at distance r from the pumped well.

Thus, $$T = \frac{264Q}{s}$$

and, $$S = \frac{0.3\ T\ t_o}{r^2}$$

Where: T = Transmissivity (gpd/ft)

Δs = Change in drawdown for one log cycle

t_o = Time intercept at zero drawdown (days)

r = Distance to observation well (ft)

S = Storage coefficient

Drawdown at any distance and time, within the radius of influence, can then be estimated by substituting the calculated T and S values into the original equation.

Assumptions:

The Cooper-Jacobs equation uses similar assumptions as listed for the Theim equation except that the cone of depression need not be at equilibrium.

THEIS RECOVERY FORMULA

Application: For estimating the transmissivity of an aquifer from the observation of the rate of recovery of water level in an observation well near the pumped well.

Calculations: The most convenient and preferred use of the Theis Recovery formula requires a semi logarithmic plot of residual drawdown s^1, against the ratio t/t^1; where t represents the elapsed time since the start of the pump test, and t^1 is the time of recovery. Residual drawdown is plotted on the arithmetic scale, and t/t^1 is plotted on the logarithmic scale. With sufficiently long recovery time, the data should provide a straight line plot from which Δs^1 over one log cycle is then used to compute transmissivity, T, in accordance with the following formula:

$$T = \frac{264Q}{\Delta s^1}$$

ANALYTICAL METHODS FOR STEP DRAWDOWN TESTS

For calculation of trasnmissivities and storage coefficient using step drawdown pump test data, the following techniques may be useful:

1. Transmissivity is related to hydraulic conductivity and can be estimated from the formula:

$$T = Kb$$

Where: T = Transmissivity (gpd/ft)

K = Hydraulic conductivity (gpd/ft^2)

b = Saturated thickness of aquifer (ft)

If the aquifer is stratified, the T values for individual strata should be calculated based on applicable values for K and b, and the results added to determine the transmissivity for the entire aquifer.

2. Graphical plot of drawdown vs log time for one step produces a straight line for drawdown; the drawdown over one log cycle can then be used for the calculation of transmissivity as follows:

$$T = \frac{264Q}{\Delta s}$$

Where:
T = Transmissivity (gpd/ft)
Δ s = Drawdown for one log cycle (ft)
Q = Pump discharge (gpm)

3. The storage coefficient (S) is related to transmissivity and can be calculated as noted previously in the Cooper-Jacobs method.

Detailed description and illustration of the various techniques for collecting and analyzing pumping tests are provided in Groundwater and Wells by Driscoll (1986).

Table 2 Values of *W(u)* for Various Values of *u*

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
X 1	0.219	0.049	0.013	0.0038	0.0011	0.00036	0.00012	0.000038	0.000012
X 10^{-1}	1.82	1.22	0.91	0.70	0.56	0.45	0.37	0.31	0.26
X 10^{-2}	4.04	3.35	2.96	2.68	2.47	2.30	2.15	2.03	1.92
X 10^{-3}	6.33	5.64	5.23	4.95	4.73	4.54	4.39	4.26	4.14
X 10^{-4}	8.63	7.94	7.53	7.25	7.02	6.84	6.69	6.55	6.44
X 10^{-5}	10.94	10.24	9.84	9.55	9.33	9.14	8.99	8.86	8.74
X 10^{-6}	13.24	12.55	12.14	11.85	11.63	11.45	11.29	11.16	11.04
X 10^{-7}	15.54	14.85	14.44	14.15	13.93	13.75	13.60	13.46	13.34
X 10^{-8}	17.84	17.15	16.74	16.46	16.23	16.05	15.90	15.76	15.65
X 10^{-9}	20.15	19.45	19.05	18.76	18.54	18.35	18.20	18.07	17.95
X 10^{-10}	22.45	21.76	21.35	21.06	20.84	20.66	20.50	20.37	20.25
X 10^{-11}	24.75	24.06	23.65	23.36	23.14	22.96	22.81	22.67	22.55
X 10^{-12}	27.05	26.36	25.96	25.67	25.44	25.26	25.11	24.97	24.86
X 10^{-13}	29.36	28.66	28.26	27.97	27.75	27.56	27.41	27.28	27.16
X 10^{-14}	31.66	30.97	30.56	30.27	30.05	29.87	29.71	29.58	29.46
X 10^{-15}	33.96	33.27	32.86	32.58	32.35	32.17	32.02	31.88	31.76

AQUIFER TEST DATA SHEET

Date ____________
Page _______ of ______

PROJECT ____
Well Designation ______________________________ Type of Test ______________________
Total depth ______________________________ Well head elev. ______________________
Pump inlet depth ________________________ Well diameter (I.D.) __________________
Screened interval __________ to __________ Filter pack diameter (O.D.) ______________
Type of perforations and size ____
Filter material and grade ____
Test Conducted By ______________________ Assisted By ______________________

Clock time	Elapsed time	Δt	Depth to water	Drawdown	Meter		Δ gallons	
					gpm	gallons		

Questa Engineering Corporation

CIVIL AND ENVIRONMENTAL ENGINEERS

September 8, 1987

Dear Water Well Owner:

From the 8th to the 11th of September, 1987, Questa Engineering Corporation will be pump testing a water well located within ¼ mile of your well. Your water well is beyond the predicted influence of our pump test; however, if you feel that the water level in your well has been influenced during that period, please contact us so that we may add such information to our pump test evaluation. Please include the following information:

- Static water level (depth from surface to water level when pump is not operating;
- Frequency of pump operation (day and hours of operation, if possible); and,
- How was your well influenced?

Please send this, and any other pertinent information, to the undersigned at:

Questa Engineering Corporation
P.O. Box 356
Point Richmond, CA 94807

Sincerely,

Norman N. Hantzsche, P.E.
Managing Engineer

RCE 24570

Ref.: 86172N2

(415) 236-6114 (FAX) 236-2423
P.O. Box 356 1220 BRICKYARD COVE ROAD POINT RICHMOND, CA 94807