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ΕΛΛΗΝΙΚΗ ΤΕΧΝΙΚΗ ΠΡΟΔΙΑΓΡΑΦΗ

HELLENIC TECHNICAL SPECIFICATION

Δοκιμαστικές αντλήσεις υδρογεώτρησης

Water well pumping tests

Pricing class: **6**

Preamble

This Hellenic Technical Specification revises and replaces ELOT TS 1501-08-09-06-00:2009.

This Hellenic Technical Specification was prepared by Experts and checked and evaluated in its field by a Supervisor/Specialist - Expert, who assisted the work of the Technical Committee ELOT/TE99 “Specifications of Technical Works”, the secretariat of which belongs to the Directorate for Standardisation of the Hellenic Organization for Standardization (ELOT).

The text of this Hellenic Technical Specification ELOT TS 1501-08-09-06-00 was adopted on 17.3.2023 by ELOT/TE 99 in accordance with the Regulation on the drafting and publication of Hellenic Standards and Specifications.

The European, international and national standards referred to in the standardisation references are available by ELOT.

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Content

Introduction

This Hellenic Technical Specification (HTS) is part of the technical texts originally prepared by the Ministry for the Environment, Spatial Planning and Public Works and the Institute for Constructions Economy (IOK) and was subsequently edited by ELOT in order to be applied to the construction of national public technical works, with a view to produce works that are robust and capable of meeting and satisfying the needs which have dictated their construction, and be beneficial for the society as a whole.

Under a contract between NQIS/ELOT and the Ministry for Infrastructure and Transport (online publication number 6ΕΟΒ465ΧΘΞ-02Τ), ELOT was assigned the editing and update as 2nd Edition of three hundred fourteen (314) Hellenic Technical Specifications (HTS), in accordance with the applicable European Standards and Regulations and the procedures laid down in the Regulation on the drafting and publication of Hellenic Standards and Specifications and in the Regulation on the establishment and operation of Technical Standardization Instruments.

This Hellenic Technical Specification was prepared by the contractor of the restricted tender No 1/2020 for the award of the work “Revision of the 1st edition of 314 HTS” (online publication number ΩΕΕΑΟΞΜΓ-ΞΗΔ), checked and evaluated in its field by a Supervisor/Specialist - Expert and submitted for Public Consultation. It was approved by the Technical Committee ELOT/TE 99 “Specifications of Technical Works”, which was set up by the Decision of the Managing Director of the NQIS, Δν.Σ. 285-19/08-02-2019 (ΑΔΑ6ΩΛΡΟΞΜΓ-15Ξ).

This HTS covers the requirements arising from the EU law, the relevant New Approach Directives currently in force and the National Law, and refers to and is compatible with harmonised European standards.

Water well pumping tests

1 Objective

The purpose of this Technical Specification is to define the requirements for the execution of pumping tests in productive drilling.

This work takes place after the purification and development of the water well, which is the subject of the Technical Specification ELOT TS 1501-08-09-05-00.

2 Standardization references

This Technical Specification incorporates –by way of references– provisions of other publications, whether dated or not. These references refer to the respective parts of the text and a list of these publications is presented thereafter. In case of references to dated publications, any subsequent amendments or revisions thereof shall apply to this document when incorporated in it by means of amendment or revision. With regard to references to undated publications, their latest version shall apply.

ISO 14686	*Hydrometric determinations – Pumping tests for water wells – Considerations and guidelines for design, performance, and use*
ANSI/AWWA A100-06	*"Water Wells" (appendix E) -- Υδρογεωτρήσεις, (Παράρτημα Ε)*
ASTM D4381-84 (2001)	*Standard Test Method for Sand Content by Volume of Bentonitic Slurries.*
ASTM D5716-95 (2000)	*Standard Test Method for Measuring the Rate of Well Discharge by Circular Orifice Weir*
ELOT TS 1501-08-09-04-00	*Pumps for water wells - Αντλητικά συγκροτήματα υδρογεωτρήσεων*
ELOT TS 1501-08-09-05-00	*Water wells cleaning and development - Καθαρισμός και ανάπτυξη υδρογεώτρησης*

3 Terms and definitions

The following terms and definitions are used in this Technical Specification:

3.1 Pumping tests

It is referred to the pumps carried out on productive drillings in order to determine their maximum potential. The pumping test can give information on the water drilling performance, the hydraulic properties of the aquifer and the underground flow. Pumping tests take time and are expensive. This is why they need to be properly designed to obtain reliable data.

The pumping tests are divided into tier pumps and fixed-flow pumps. Information on the hydraulic properties of the well is obtained from the first and from the second information on the hydraulic characteristics of the aquifer and its behaviour on an extended holding. More information is given to chefs. 4 and 5 of this. The pumping tests shall follow as defined in ISO 14686.

The following shall be taken into account for the design of the pumping tests:

1. The pump must be able to draw the maximum flow rate from the specific depth.

2. The duration of the pumping test depends on the pumping supply, the distance of the piezometer, the transferability of the aquifer and the radius of the survey area. For pressure aquifers, pumping at least 24 hours is necessary to establish or have hydrogeological boundaries.

3. When performing the pumping test, no adjacent drilling must be operated, which may affect the drilling.

4. The piezometers for measuring the level shall be within the radius of effect of the drilling pumped.

The groundwater level is measured by weights or autograph instruments in the pumped drilling and in adjacent observation drilling (piezometers), at specified intervals, and is recorded in special forms.

Before starting the pumping test, the initial groundwater level in the drilling shall be measured and the level restored shall be measured after discontinuation. It should be noted that level recovery measurements are an integral part of any pumping test.

For the pumping tests, a log of water well testing shall be drawn up consisting of:

a. the pumping data sheet, which records the main elements of the pumping tests;

b. the test well abstraction sheet, recording the data and observations of the pumping tests (by step or continuous pumping) and the level recovery measurements after the pumping tests.

3.2 Pitot device

The Pitot tube is a measuring device used to measure fluid speed and is a type of funnel. The Pitot tube can measure the static properties as well as the calm properties of a fluid. The fluid in the middle tube of the device (Figure 1) is slowed down to rest, while openings in the outer tube measure the static pressure of the fluid. The velocity of the current is calculated from the difference between idle pressure and static pressure. When the ultrasonic flow rate is measured, a shock wave is formed upstream of the Pitot tube.

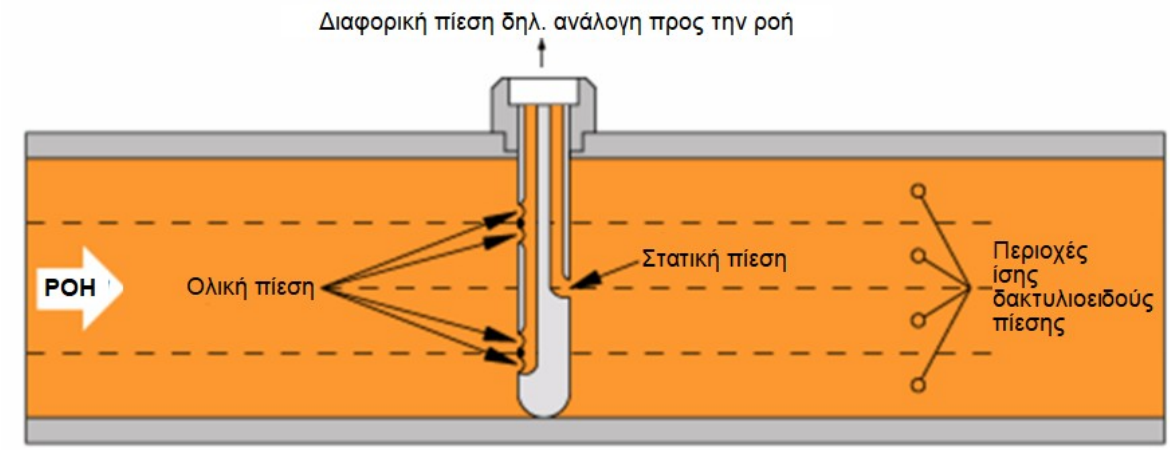

Figure 1: Standard Pitot tube layout

Source: Instrumental tube.com

Διαφορική πίεση δηλ. ανάλογη προς την ροή	Differential pressure i.e. flow-proportional
POH	FLOW
Ολική πίεση	Total pressure

Στατική πίεση	Static pressure
Περιοχές ίσης δακτυλιοειδούς πίεσης	Areas of equal ring pressure

3.3 Critical supply

It is the flow value beyond which the level drop begins to grow sharply with the increase in the flow rate. (Figure 2)

3.4 Drilling potential (provision of operation)

As an operating or useful supply ($Q_ε$) a flow rate less than or equal to the critical supply (Qε ≤ Qk).

A typical example of estimating the critical flow and operating flow of a well is described in the diagram below (Figure 2) drop-off, which is also a characteristic drilling curve. A curve drawing requires a step-by-step pumping test with at least three (3) different benefits.

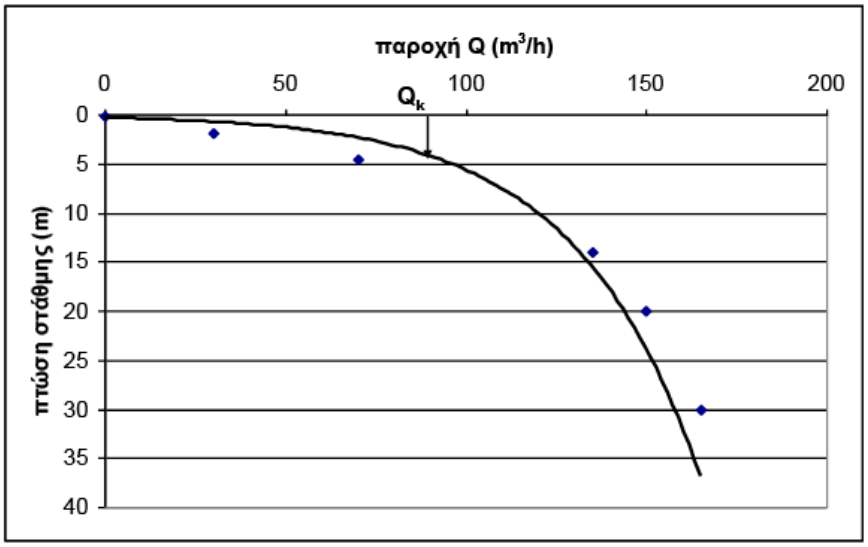

Figure 2: Characteristic water drilling curve

παροχή Q (m^3/h)	flow Q (m^3/h)
πτώση στάθμης (m)	level drop (m)

4 Requirements

The pumping tests aim to determine the water well's ability to deliver water (critical flow, useful flow, specific capacity, etc.) and to calculate the hydraulic parameters of the aquifers.

Flow measurements shall be made on a volumetric basis or using a Pitot device or a water meter in accordance with the instructions of the competent authority and the water level shall be measured by means of a precision electrical calculator in the piezometric tube. Other ways of measuring level and flow are given in Annex C to ISO 14686.

The technical characteristics of the pump assembly (pump diameter, turbine diameter, mounting depth, horsepower kg) must be determined by the competent authority on the basis of the Technical Report or Study and are binding on the Contractor, regardless of whether the expected benefits can be achieved by

other diameter pump assemblies. The characteristics referred to in Technical Specification ELOT TS 1501-08-09-04-00 shall also apply to pump assemblies.

The pumping assembly must be capable of continuous operation for long-lasting pumping.

The flow rate shall be adjusted by a valve or a change of engine speed where possible.

The water must be drained at an appropriate distance so that the pumping test is not affected.

The Contractor must have specialised in similar tasks and certified experience of scientific and technical personnel during extraction, as well as the necessary measuring instruments. The details of the pumping must be shown in special fiches. At the end of the pumping, water level reset measurements must be made. The level recovery time shall be at least the same as the pumping time, in accordance with ISO 14686.

The Contractor must submit to the Competent Authority for approval a detailed programme of the pumping tests, analysing and documenting the measurement methodology and specifying the staff who will carry out the work. The pumping test must be carried out in accordance with the written programme drawn up by the Competent Authority.

The drilling water at the end of the pumping test should be free from solid granules of sludge or fine sand and approximately clear.

Evacuation near the drilling field must not take place as it may lead to alteration of the results of the measurements, particularly in areas with permeable surface layers.

4.1 Minimum requirements for the execution of pumping tests – Key assumptions

The main hydraulic parameters are transferability factor (T), storage factor (S) and hydraulic conductivity (k). Practically, a drilling is pumped and the rate of drop of groundwater level in pumping drilling is recorded in one or more adjacent observation drillings.

For the study of the flow in hydrostemutical projects (drilling, wells, trenches) and the calculation of hydraulic parameters of aquifers, some assumptions should be made regarding hydraulic conditions in aquifers, as well as drilling and observation drilling.

These assumptions are as follows:

1. The aquifer must be isotropic and homogeneous.
2. The aquifer shall be of infinite extent with a horizontal impenetrable background.
3. The initial piezometric level shall be at rest before starting pumping.
4. All changes in the position of the piezometric surface should be due only to the effect of pumping.
5. The flow must be laminated (non-turbulent, so Darcy’s law is in force).
6. Groundwater must have a constant density and viscosity.
7. The flow of groundwater shall be horizontal (without vertical component).
8. All groundwater flow must be radial to the drilling and this means that the values of storage and transition must be independent of the direction of the flow.

9. The drilling must be complete or complete (complete or fully penetrating borehole), i.e. drilling all the aquifer up to the impenetrable background and having filters throughout its thickness (Figure 3).

10. The diameter of the drilling must be very small in relation to the thickness of the aquifer, meaning that the storage of water in the drilling must be negligible.

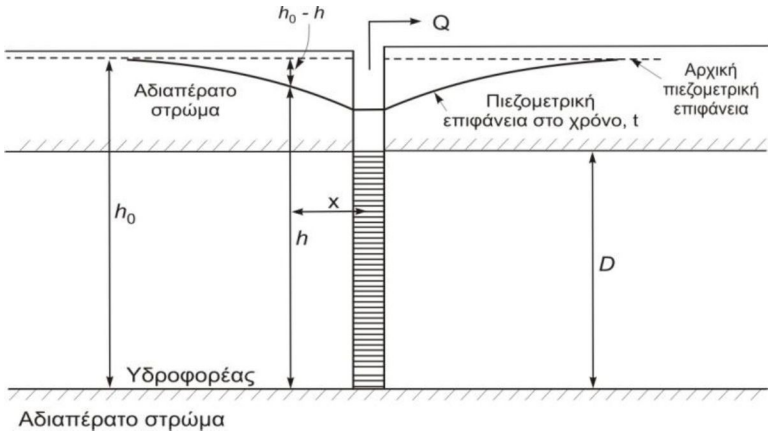

Figure 3: Example of perfect drilling that pumps a pressured aquifer

Αδιαπέρατο στρώμα	Impermeable mattress
Υδροφορέας	Aquifer
Πιεζομετρική επιφάνεια στο χρόνο, t	Piezometric surface in time, t
Αρχική πιεζομετρική επιφάνεια	Initial piezometric surface

These assumptions are general and additional assumptions apply where appropriate. Some of these may not apply such as homogeneity and isotropy of aquifers. In case the aquifer is highly anisotropic and the drilling is not complete, the deviation may be significant. Other conditions, such as horizontality, do not significantly affect the accuracy of the results.

For the study of flow in pumped boreholes and the calculation of hydraulic parameters, two types of flow are distinguished: permanent and non-permanent flow.

Note: According to paragraph 4.4 of ISO 14686, it is considered necessary to drill at least four observation wells around the productive drilling in order to better monitor the behaviour of the aquifer during the conduct of the pumping test. The locations and characteristics of these boreholes are determined in the Study.

4.2 Pumping test equipment requirements

The drafting of the pumping test is necessary for its successful execution. Once the type and duration of pumping has been decided, appropriate equipment must be ensured. The following equipment is required to perform the pumping tests:

(1) Pitot device or water meter for measuring benefits

(2) Capacitance level gauge, 0.5 -1.0 cm

(3) Pumping assembly equipped with a flow adjuster (e.g. control) or capable of continuous operation for a long time.

(4) Generator (if it is not possible to supply directly from the grid).

The Contractor must submit to the Competent Authority a file containing the technical data and characteristics of the above equipment and recent calibration reports of the measuring devices (1) and (2). The use of the above proposed equipment shall be subject to the approval of the Competent Authority.

5 Methodology for carrying out the work

5.1 Pumping tests

5.1.1 General

After completion of the development work, the drilling must be left idle for at least 24 hours in order to restore the water level to rest. During this 24-hour period, level measurements must be carried out in order to certify the re-establishment of the hydrostatic level.

Subsequently pumping tests should be carried out with the objective of:

(a) the determination of hydraulic parameters and the construction evaluation of the drilling;

(b) the evaluation of the hydrogeological characteristics of the aquifer(s); and

(c) the determination of the best operating sizes of the well.

On the basis of the general characteristics of the drilling, such as those recorded during the monitoring of the development operations, an appropriate pump must be placed in the borehole capable of delivering a supply of 150 % of the estimated or expected operating supply. The pump shall be accompanied by all necessary power sources (e.g. generators), control systems, piping and flow rate devices for pumping tests.

The pumping tests to be carried out should include the following:

(a) a step-by-step pumping test; and

(b) stable flow pumping test.

When performing the pump tests, the following measurements shall be made:

1. Water level measurement with an electric calibre in the water drilling and the piezometer satellite.
2. Determination of sand content by one of the following methods:
    I. sand content kit according to the standard ASTM D4381-84 (2001)
    II. cone Imhoff (settling time at least 10 min)
    III. for contents of less than 100 ppm a Rossum Sand Tester device shall be used in accordance with Specification ANSI/AWWA A100-06.
3. Measurement of pumping flow by one of the following methods:
    I. combination of timing and titration with water meter
    II. nozzle method, according to the standard ASTM D5716-95 (2000)

III. combination of timing and titration with a vessel of known volume (only for facilities less than 10 m^3/h)

4. Measurement of temperature and electrical conductivity of water with a portable electronic measuring device (conductor meter).

It is clarified that pumping equipment should not be considered in a drip if it is expected to return the well to hydrostatic equilibrium after pumping at any flow rate and by any technique (e.g. tiered pumping, step pumping, etc.).

The measurement data of the supply meter and the weightometer shall be entered on pre-printed forms, depending on the time of the measurements.

Data on the resetting of the aquifer level after stopping pumping must also be kept (on the same forms).

5.1.2 Tier pumping test

The main objective of this test is to obtain data for the extraction of the “typical drilling curve”, which identifies “critical flow rate”, “operating supply” and “level drop available”. From the elements of this test it is also possible to identify the ‘typical drilling losses’ which are an indicator of the design adequacy and structural success of the well.

During the test, pumping must be carried out at a minimum of four pumping steps, with progressively increasing flow rates. The duration of each step shall be such as to result in a stabilisation of the water level as a function of logarithm of time. It is obviously not possible to predetermine an exact duration of each pumping step, but it is estimated that it will last from 100 to 120 minutes. During each pumping step the flow rate shall be maintained at a constant range of 5 per cent, either by a flow control valve or by adjusting the pump motor.

After stabilisation of the water level, the pumping supply must be increased at the next pumping tier, without interrupting the pumping. After completion of the last pumping step, level recovery measurements shall continue to be taken. The ISO 14686 standard stipulates that the last stage shall be performed under flow rate approximately equal to the estimated maximum drilling flow rate, but no excessive level drop is observed.

The minimum frequency of taking level measurements at the pumped drilling during pumping and during reset is then specified.

The times following the start of pumping or after a change of pumping step or after the start of the level restoration shall be as follows:

Table 1: Frequency of level measurements during pumping test
(Source: paragraph 4.6.2 of ISO 14686:2003)

Time from start of pumping test	Frequency of groundwater level measurements
0-10 min	0.5 min
10-20 min	2 min
20-60 min	5 min
60-100 min	10 min
100-300 min	20 min
300-1,000 min	50 min
1,000-3,000 min	100 min

>3 000 min	200 min

Level recovery measurements shall be made for the total recovery time, defined either as a time equal to the total pumping time or as the time required to restore a level of 90 % (whichever occurs first).

In addition to water level measurements, measurements of the following parameters shall be carried out during tier pumping test in order to obtain a complete picture of drilling behaviour at progressively increasing pumping rates:

1. Water content in sand
2. Water temperature °C
3. Electrical water conductivity (μS/cm)

The first measurement of these parameters shall be made during the first five minutes (from the beginning of pumping or after the change of pumping step) and then every 15 min.

5.1.3 Pumping test of constant flow

Based on the data from the step-by-step pumping test, the aquifer conditions (free or pressured aquifer, critical flow rate, critical pumping level) must first be determined. These elements will form the basis for the Competent Authority's determination of the technical characteristics of the constant and long-lasting pumping test (period of pumping, pumping supply, etc.). The objective of this test is to examine the behaviour of the drilling under simulated prolonged operation conditions in the estimated pumping supply.

The constant flow test pumping shall be started after the completion of the step-by-step pumping test level reset measurements. The duration of the constant flow pumping test shall be at least 24 h in the case of pressure aquifers and at least 48 h for free aquifers. During pumping it shall be sought to maintain a constant flow rate within a range of 10 per cent, either by a flow control valve or by adjusting the pump motor. Recommended durations of the test, depending on the flow rate, are given in section 4.3.4 of Standard ISO 14686.

Water level measurements (when pumping and restoring level), sand, water temperature and electrical water conductivity shall be carried out in a manner and at a frequency to be determined by the Competent Authority in accordance with the evolution of the pumping tests.

Water sampling for chemical analyses may be performed during the constant flow pumping test. Sampling and subsequent chemical analyses must be carried out at the initiative, care and expense of the Project Master.

The Contractor and the Competent Authority have the obligation to inform the League in good time in order to plan the execution of the samples.

5.1.4 Pumping test failures

The Contractor must carry out the above pumping tests, in accordance with the provisions of this Technical Specification and in accordance with the instructions of the Competent Authority, without interruptions and fluctuations. The data – observations of the abstractions must be recorded in the pumping test fiches. The water pumped shall be channelled to an appropriate recipient and at a sufficient distance away from the drilling, so that the test progression is not affected.

If for any reason the pumps are interrupted or disturbed by fault of the Contractor (e.g. negligence of personnel, lack of fuel, failure of generators/pumps, etc.), as well as in the event that there is an incomplete

recording of the abstraction data and/or incorrect keeping of the pumping test fiche, the resumption of the pumping test interrupted must be ordered.

It should be stressed that the execution of the pumping tests is fundamental for the quantitative and qualitative characterisation of the well, the essential control of its construction quality and the determination of the critical hydrogeological sizes.

6 Acceptance criteria of completed work

6.1 Completion control of the pumping test

The work is deemed to have been completed with the preparation, submission and approval of the Technical Report on Pumping Tests, which should follow what is stated in the Chapter 9 of ISO 14686 Standard and which must include as a minimum:

1. Description of the geological characteristics of the water well field.
2. Description of the method of execution of the pumping tests and equipment used.
3. Processing and presentation of the results of the pumping tests, drawing up critical flow diagrams, a fall-down and level-time reset diagram, to calculate hydraulic parameters.
4. Tables with the primary field measurement data.
5. Level drop/reset diagrams as a function of time.
6. Determination of a critical supply and a useful operating supply.

7 Method of measurement of works

The measured operations of the water well pumping tests are as follows:

1. The ingress and collection of equipment shall be measured at a flat rate per field of water wells, irrespective of the number of drillings in the field.
2. The transfer one position to another, installation/disassembly of equipment (pump assembly, instruments, piping, wiring) is also calculated flat-rate per water well, regardless of the assembly to be installed.
3. The operation of a pump assembly shall be measured per hour of pumping test, according to the measurement data, irrespective of the size of the pump assembly, including all auxiliary equipment, measuring instruments and/or recordings, as well as the preparation of the Technical Report.

Annex A
(Informative)

Health, safety and environmental protection conditions

A.1 General

During the execution of the works, the applicable provisions on Occupational Health and Safety Measures shall be met and employees shall be equipped with the necessary Personal Protective Equipment (PPE) as appropriate, which must comply with the provisions of Regulation (EU) 2016/425.

The provisions laid down in the approved Health and Safety Plan (HSP)/Health and Safety File (HSF) of the work, according to Ministerial Decisions ΓΓΔΕ/ΔΙΠΑΔ/οικ/889 (ΦΕΚ/16 Β'/14-01-2003) and ΓΓΔΕ/ΔΙΠΑΔ/οικ/177 (Government Gazette, Series II, No 266/14-01-2001) shall also be strictly met.

A.2 Health and safety measures

The sources of risk in carrying out the work are as follows:

1. Power supply wiring of pumping assembly.
2. Handling of pumping complex (lifting, downhill).
3. Pressure pipe fittings (sufficient clamping controls).

It is mandatory to comply with Directive 92/57/EU, which refers to the "Minimum Health and Safety Requirements for Temporary and Mobile Works" (as incorporated into Greek Legislation by Presidential Decree 305/96) and the relevant Greek legislation (Presidential Decree 17/96, Presidential Decree 159/99 etc.).

Workers must in all cases be equipped with the required personal protective equipment (PPE), depending on the object and location of the work to be carried out and the type of equipment used. The PPE must be in good condition, free of damage, bear a CE marking and a declaration of conformity in accordance with the provisions of Regulation. (EU) 2016/425 and fall under the following Standards:

Table A.1 — Requirements for PPE

Type of PPE	Relevant Standard
Protective gloves against mechanical risks	ELOT EN 388
Industrial safety helmets	ELOT EN 397
Protective clothing – General requirements	ELOT EN ISO 13688
Personal protective equipment – Safety footwear	ELOT EN ISO 20345

A.3 Measures of environmental protection

In order to achieve environmental protection, the measures that can be taken are:

1. Removal of water to suitable (natural or artificial) recipients

2. Ensuring water well drilling from any pollution in the execution of operations

The Environmental Conditions of the project shall always apply.

Bibliography

[1] Law 1568/85 (Government Gazette, No. 177A/18.10.85), *“On the health and safety of workers”.*

[2] Directive 98/83/EC: Council Directive of 3rd November 1998 on the quality of water intended for human consumption

[3] Presidential Decree 17/96 (Government Gazette, No. 11A/96*), “Implementation of measures to promote improvements in the health and safety of workers” in compliance with Directive 89/391/EEC and 91/383/EEC, as amended by Presidential Decree 159/99*

[4] Presidential Decree 105/95 (Government Gazette, No. 67A/95*), “Minimum requirements for safety and/or health marking at work, in compliance with Directive 92/58/EEC”.*

[5] Presidential Decree 305/96 (Government Gazette, No 212A/29.8.96), *“Minimum safety and health requirements to be applied to temporary or mobile construction sites, in compliance with Directive 92/57/EEC”, in conjunction with Circular No 130159/7.5.97 of the Ministry of Labour and Circular No 11 (Protocol No. Δ16α/165/10/258/ΑΦ/ 19.5.97) of the Ministry of the Environment, Public Works and Public Works, concerning the above Presidential Decree*

[6] Presidential Decree 338/2001 (Government Gazette, No. 227/A/2001), *Protection of workers’ health and safety at work from risks arising from chemical agents.*

[7] Presidential Decree 396/94 (Government Gazette, No. 220A/94), *“Minimum safety and health requirements for the use by workers of personal protective equipment at work, in compliance with Directive 89/656/EEC”.*

[8] Presidential Decree 397/94 (Government Gazette, No. 221/A/94), *Minimum safety and health requirements for the manual handling of loads involving a risk in particular to the back and back of workers in compliance with Council Directive 90/269/EEC.*

[9] Regulation (EU) 2016/425 *of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC.*

[10] ELOT EN ISO 22282-4*, Geotechnical investigation and testing – Geohydraulic testing – Part 4 Pumping tests -- Γεωτεχνικές έρευνες και δοκιμές – Δοκιμές διαπερατότητας – Μέρος 4: Δοκιμές άντλησης*

[11] ELOT TS 1501-08-09-01-00, *Water wells drilling -- Διάνοιξη υδρογεωτρήσεων.*