Interreg
Italy - Croatia
MoST

MoST

Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation

Interreg CBC Italy-Croatia 2014.-2020.

ABOUT THE PROJECT AREA

The Neretva valley is an important agricultural area where citrus fruits are mostly grown (4000 wagons of mandarins are produced each year) followed by watermelons and plums. Vegetables grown in the valley are tomatoes, lettuce, cucumbers, etc. Olive cultivation that dates back to the Narentine principality is also important.

The rich soil is interspersed with canals to create conditions for growing various agricultural crops, in particular a variety of citrus fruits such as lemons, oranges, clementines, etc. On top of all that, as you probably already know, the Neretva is the true capital of mandarins. It is estimated that about 1.4 million trees have been planted in the area that bear rich fruit every year.

The Neretva area has experienced the biggest changes over the past few decades. It used to be a wetland area surrounded by the hydrophilic vegetation, while today the swamps are drained and the land is more adapted to the cultivation and processing of fruits.

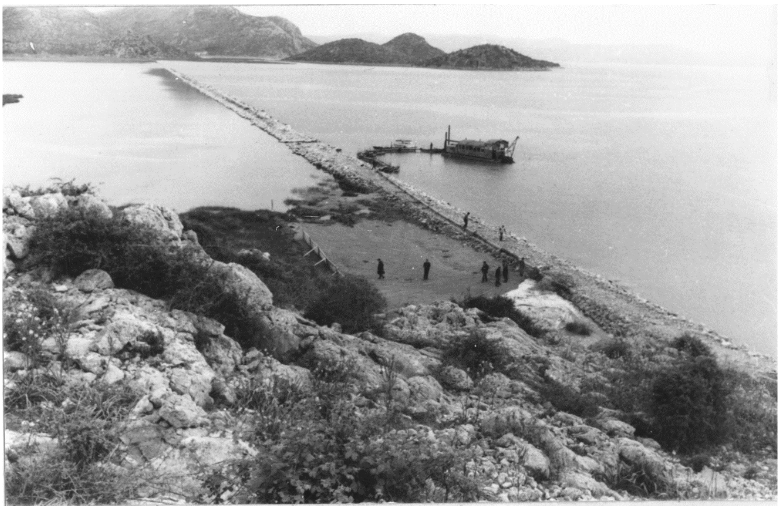


Figure 1. Coastal embankment Diga during construction

This original wetland area underwent the most intensive transformation from the 1950s to the 1980s when modern land reclamation began and was essentially completed. The method of draining wetlands of the Neretva Delta and turning them into agricultural areas is called "jendečenje" (creation of small canals). It is a technique of digging canals and removing sediments from them in order to obtain material for filling moist soil.

In the second half of the 20th century, research work in the wider area of the lower Neretva River within the territory of the Republic of Croatia began, with the aim of infrastructure construction for land use change. The research works covered various locations: Opuzen Ušće, Vidrice, Crepina, Jasenska and Mala Neretva. Already in the 1960s the drainage of Lake Modrič and the construction of the coastal embankment Diga began, that still represents 1800 m long dividing line between the valley and the sea, from the mouth of the Neretva to the mouth of the Mala Neretva. Then, channel system and pumping stations for drainage of the areas surrounding Opuzen Ušće and Vidrice were constructed.

In the area of Opuzen Ušće channels converge towards the intake basin of the Modrič pumping station. With an installed capacity of 19.6 m^3/s, this station pumps water into the sea at the mouth of the Mala Neretva maintaining favorable water table in the shallow unconfined aquifer. Drainage of the Vidrice area is based on the operation of the pumping station Prag. With a slightly smaller capacity (compared to the pumping station Modrič) consistent with the amount of water in the area, the station Prag pumps water from the area of Vidrice to Mala Neretva, which then flows into the sea.

The Mala Neretva subsystem was initially conceived as a flood protection system that catches a part of the flood wave and relieves the flow of the Neretva downstream from Opuzen. Considering the level of infrastructure within the inundation area, the initial idea was abandoned and today Mala Neretva represents the freshwater retention suitable for irrigation of Mala Neretva and Crepina areas. The regulation of Mala Neretva is carried out by two sluices. The upstream sluice gate is located in Opuzen, 200 m from the point of separation of the Mala Neretva from the main course of the Neretva. For most of the year, the sluice is closed to preserve the water quality of the Mala Neretva. At the mouth of the Mala Neretva a downstream sluice has been set up in order to regulate the water level of the Mala Neretva and prevent the intake of salt water upstream thus ensuring appropriate water quality of the Mala Neretva for irrigation.

After the construction of the water management infrastructure the natural water regime has been changed. Due to the groundwater level lowering, a gradient from the sea water has been increased thus the inflow of the sea water towards inland has been enhanced. As a consequence, additional effort has to be given to ensure the water quality conservation to preserve the agricultural production.

The sea water intrusion (SWI) caused salinization of water and soil along the Neretva valley area, from Opuzen town to the east to Diga embankment to the west, is shown to be influenced by different external loadings and conditions specific for this area. Besides the oceanographic, hydrological, climatological and meteorological conditions, the operational regime of water management system leads to more complex and dynamic spatio-temporal changes in the salinity of both ground and surface water.

PROJECT GOALS

Main goals of MoST projects are as follows: i) increase of the response capacity to climate changes and their consequences, ii) increase of the international recognition and competitiveness in SWI induced problems in coastal aquifer systems, iii) empowering of the internationalization of research groups, iv) conductance of the scientific investigation adjusted to very specific conditions relevant for pilot project area with final goal to develop adaptation plans to climate changes.

Project goals achievement has been ensured through the accomplishment of project and research activities: i) in-situ investigation work and site characterization, ii) establishment of the real time monitoring system, iii) laboratory activities and monitoring and iv) numerical modeling.

After the primary research activities are done, SWI vulnerability assessment of the project area and adaptation plans have been developed with final goal to ensure the long term and sustainable water quality along the project area in the future.

IN SITU INVESTIGATION AND SITE CHARACTERIZATION

As a part of the project activities, a program of research works was carried out with the aim of determining the litho-stratigraphic definition of the aquifer system of the Opuzen Ušće and Vidrice areas. The program includes a number of field activities, application of geoelectrical tomography (ERT), seismic reflection, geoelectric probes, performance of exploratory wells, laboratory processing of extracted samples and application of geophysical method based on the concept of electromagnetic field (AEM).

By combining different methodological approaches, the goal is to increase the reliability of the results and provide prerequisites for the development of a numerical model of SWI into the coastal aquifer and thus increase capacity in predicting salinization of the project area.

Tomographic profiles demonstrate the field of the resistance interpreted by taking into account the properties of both aquifers and groundwater for the depth of up to 200 m where bedrock has been detected. The transition zones from one stratigraphic unit to another were determined by using seismic reflection while the borehole logs were used as a first order data to calibrate the results of geophysical methods.

Unlike conventional geophysical methods, AEM was applied for the first time in the project area and represents the only method that allows a spatially continuous description of resistance within the project area.

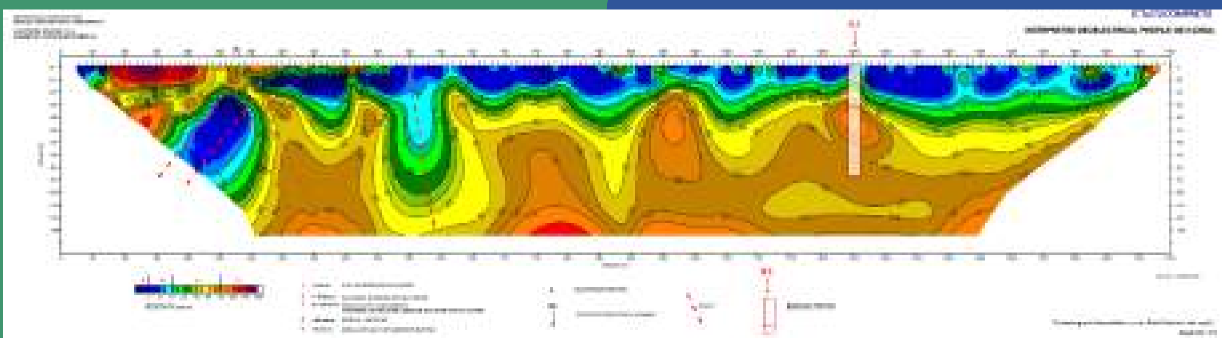


FIGURE 2. ERT PROFILE OBTAINED FOR DIGA PROFILE

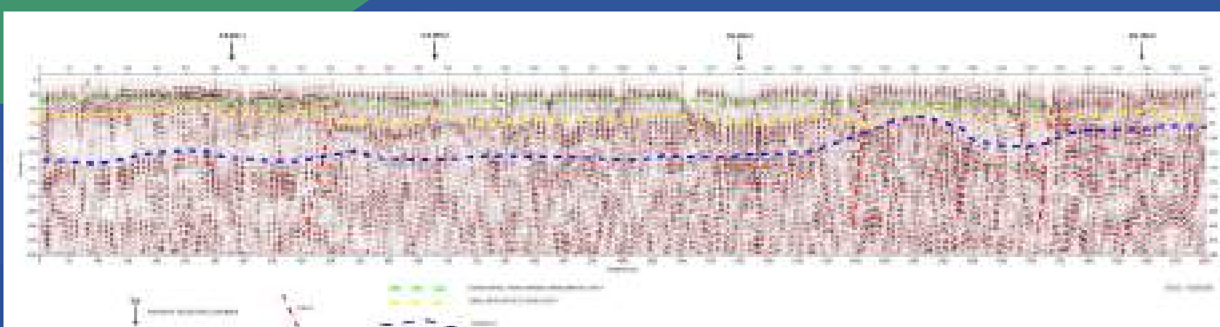


FIGURE 3. SEISMIC REFLECTION INTERPRETATION AT CREPINA PROFILE

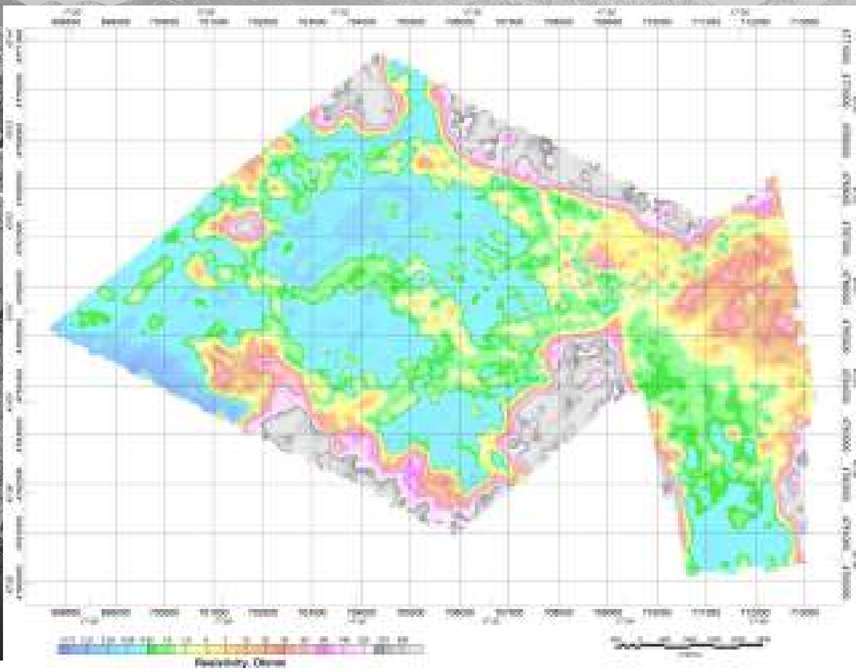


Figure 4. Resistivity field performed by AEM application at interpretation depth of 20 m

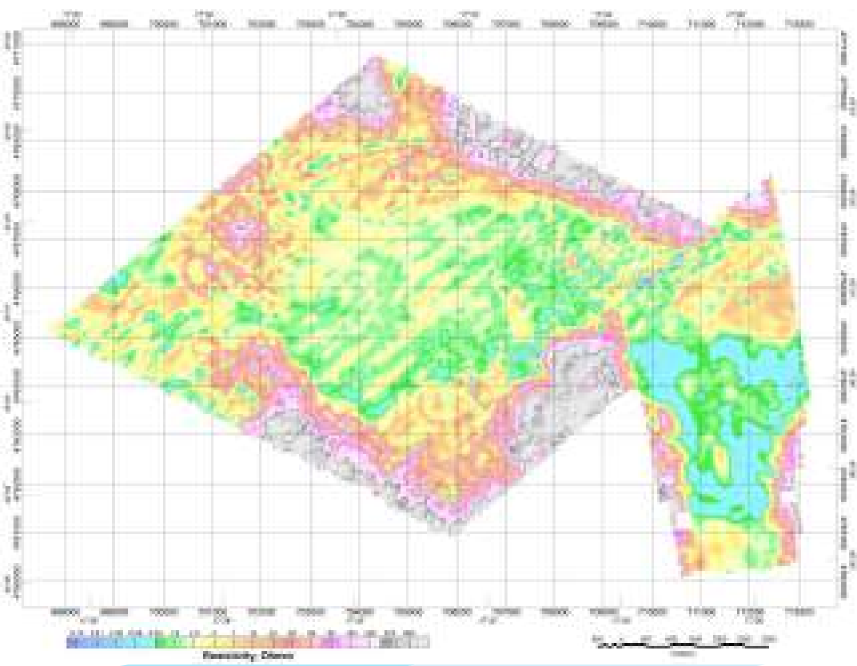


Figure 5. resistivity field performed by AEM application at interpretation depth of 50 m

Figure 6. B-2 borehole core performed at Diga profile

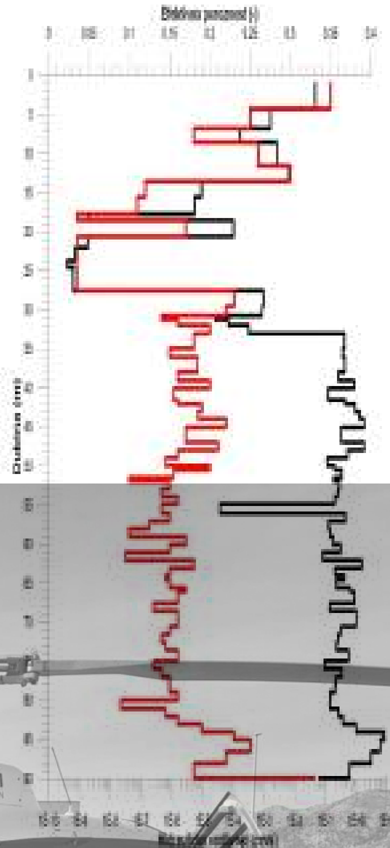
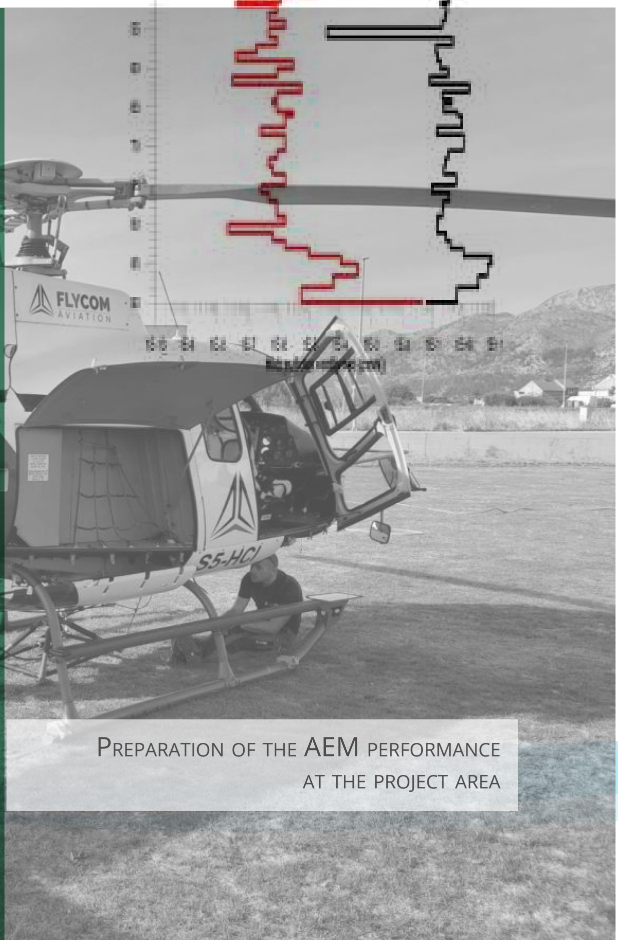


Figure 7. Hydraulic conductivity and effective porosity obtained from laboratory tests for B-2 borehole core

The distribution of lithological units have been determined by the analysis of the collected data and the interpretation of the results of the conducted research. The surface aquifer is on average 7-10 m thick, mostly composed of predominantly sandy material with the presence of clay interlayers. Below this layer, a compact clay layer has been determined the thickness of which increases from east to west and equals 20 m along the Diga profile. Bedrock has been detected at depths up to 180 m along the project area.



Preparation of the AEM performance at the project area

MONITORING ACTIVITIES

Monitoring infrastructure at the location of pumping station Modrič intake basin

For purpose of the project a monitoring system of surface and ground water in real time has been established. In total 36 different variable time series is collected on a server and is available via the MoST mobile app.

In the shallow aquifer two probes were implemented to ensure the capacity to monitor the state of water in conditions of pronounced salinity stratification. The development, implementation and improvement of the system enables the analysis of processes affecting water quality, its dynamic properties and spatial variabilities.

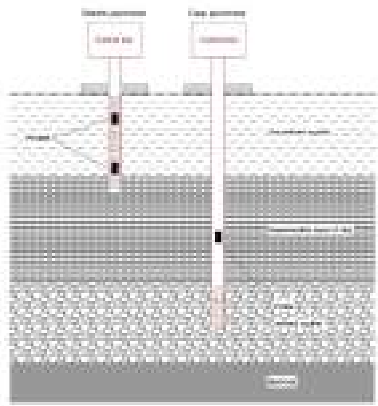


Figure 8. Shematic view of the monitoring infrastructure implementation

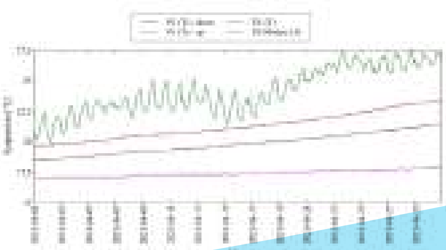


Figure 9. Insight to observed variables

Figure 10. Interior of the monitoring box at the piezometer

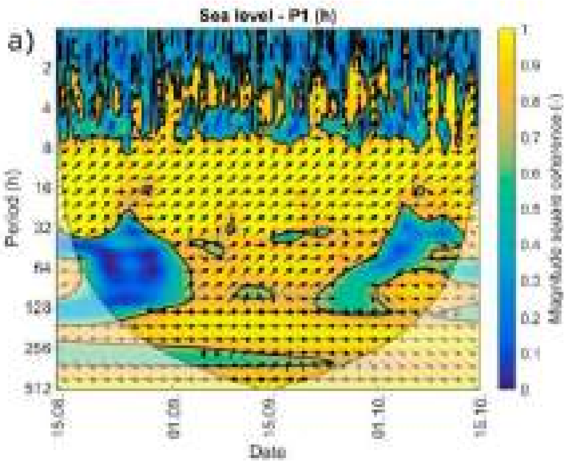


FIGURE 11. COHERENCE OBTAINED FOR OBSERVED SEA LEVEL AND GROUNDWATER PIEZOMETRIC LEVEL

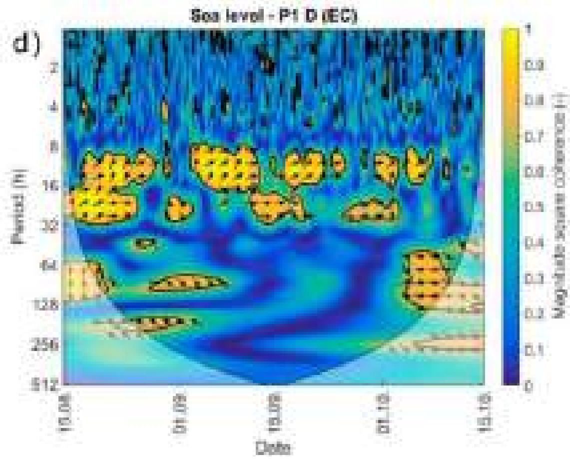


FIGURE 12. COHERENCE OBTAINED FOR OBSERVED SEA LEVEL AND GROUNDWATER ELECTRICAL CONDUCTIVITY (EC)

LABORATORY MODELING

The present state salinity conditions within the project area have been modeled under laboratory conditions. In addition, the impact of climate changes have been examined primarily through the projected sea level rise as well as the impact on the salinity status of the water in the area of interest.

The effectiveness of the application of mitigation measures to protect the coastal aquifer from SWI induced harmful effects has been tested in laboratory. This includes solutions such as injection barrier along the Diga profile and construction of recharge channel along the left bank of the Neretva, from the location of future barrier to the sea.

Given that the conditions of active seawater intrusion were detected in the project area, the barrier at Diga has not been shown to be an effective mitigation measure. On the other hand, the recharge channel in terms of functionality and water quality improvement has been classified as a very successful protection measure.

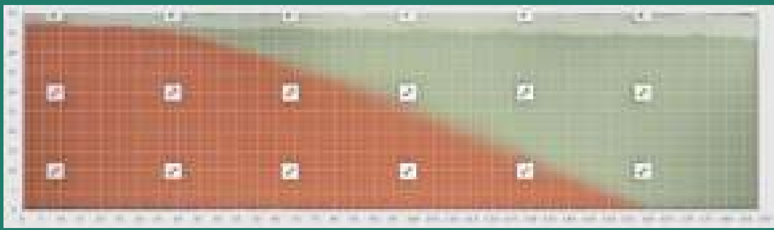


Figure 13. Laboratory experiment result of active sea water intrusion in present state

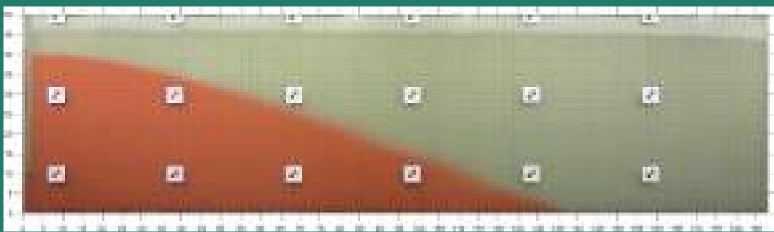


Figure 14. Laboratory experiment result of active sea water intrusion with partially submerged impermeable barrier implemented

Figure 15. Laboratory experiment result of active sea water intrusion with recharge channel implemented

NUMERICAL MODELING

For the purpose of assessing the water quality under the conditions of climate changes and implemented mitigation measures within the GMS environment, a dulal density numerical model has been implemented to simulate the spatio-temporal properties of the water salinity along the project area.

For appropriately selected boundary and initial conditions, the calibration procedure lead to the determination of the model parameters, after which the model was validated with data from the monitoring system.

The forecast of an increase of the mean sea level for 84 cm (IPCC; RCP8.5) indicates a visible deviation from the existing salinity status and an additional threat to agricultural production.

By implementing recharge channel in the left bank of the Neretva River downstream from the location of the future barrier, model results indicate a significant and long-term improvement of water status in the catchment, indicating the suitability of such a solution and the need for further technical solution development.

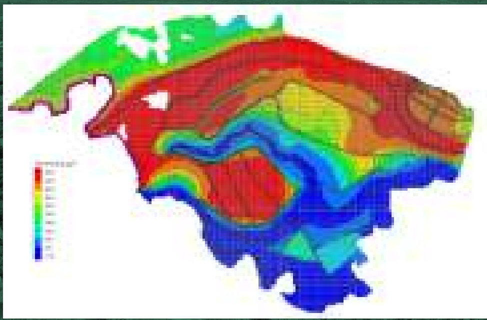


Figure 16. Present state salinity distribution characterizing shallow aquifer

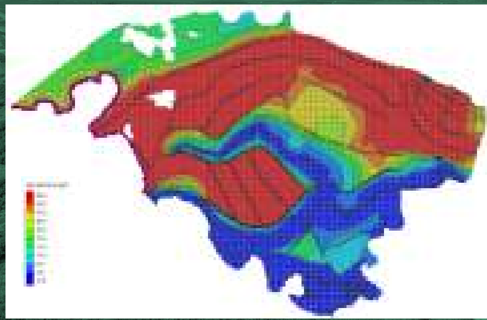


Figure 17. Salinity distribution characterizing shallow aquifer for 84 cm increase of mean sea water elevation

MITIGATION MEASURES AND EFFECTIVENESS

As a part of the project, a number of mitigation measures have been tested related to management and infrastructure measures that potentially aim to improve water quality status and reduce the intensity of SWI to the coastal aquifer system of the Neretva Delta.

The analysis of the rain and dry periods identifies different seawater intake corridors. Unlike the rain period, when the SWI is predominantly achieved through the coastal embankment Diga in the length of 2.0 km, during the dry season the dominance of sea water in the Neretva river bed is detected, turning the river into a source of salt water.

The choice of the concept of protection of the project area from the harmful effects of sea water is based on the analysis of the existing situation. After the implementation of the injection impermeable barrier along the Diga, the reduction of SWI into the coastal aquifer is improved. Given the fact that the process of SWI in the project area is characterized as active one, it is necessary to intervene in the left bank of the river Neretva. The effect of such an intervention drastically improves the state of water in the project area and represents a systematic and unique solution for protection against the harmful effects of the sea water.

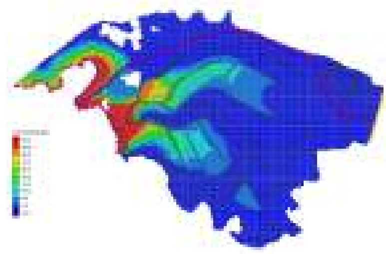


Figure 18. Present state salinity distribution characterizing shallow aquifer during rain season

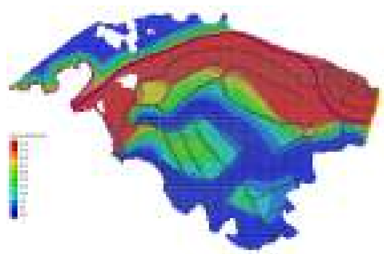


Figure 19. Present state salinity distribution characterizing shallow aquifer during dry season

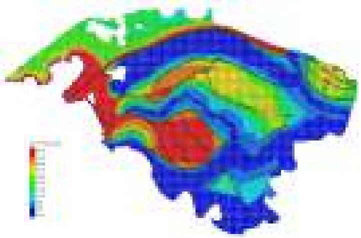


Figure 20. Salinity distribution characterizing shallow aquifer in case of barrier implementation into the river Neretva and recharge channel along the left Neretva bank

Figure 21. Salinity distribution characterizing shallow aquifer in case of impermeable barrier implementation along the Diga embankment

CONCLUSIONS

The implementation of MoST project activities lead towards the increase of the knowledge level and understanding of the processes influencing ground and surface water salinity along the Neretva valley project area. Furthermore, MoST enabled the basis and foundation as well as specific knowledge to increase the preparedness level for the climate changes response and adaptation. To minimize negative effects of climate induced changes to water quality within the river Neretva coastal aquifer system, main contribution of MoST outcomes can be summarized:

- Real time monitoring of the surface and ground water bodies has been established and implemented. Data sets and time series observed are available via the MoST mobile application and can be used to follow up water quality parameters and decision making on the irrigation activities.

- The litho-stratigraphic definition has been determined for the project area aquifer system. Multi method based geophysical, geotechnical and laboratory approach has been applied to determine existence of different geological layers, transition zones, hydraulic conductivity, effective porosity and their spatial heterogeneities.

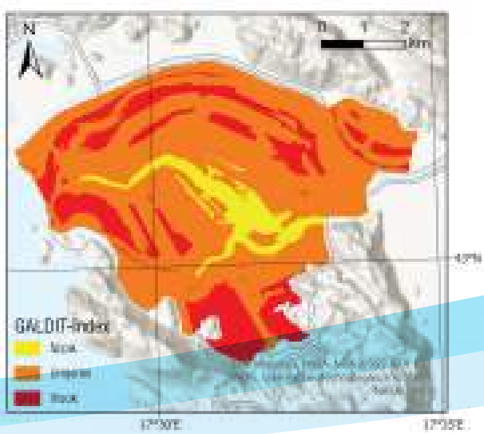


Figure 22. Present state SWI vulnerability definition

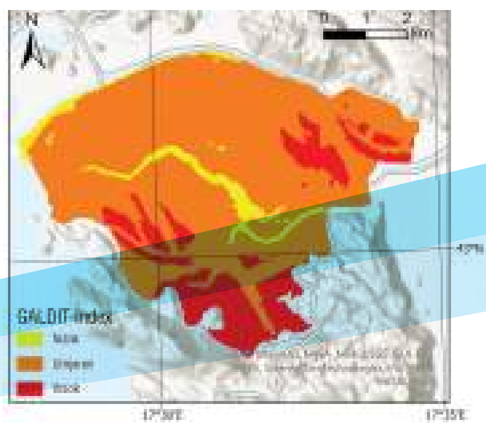


Figure 23. SWI vulnerability definition for climate change projections and implemented mitigation measures

- Taking into consideration prognostic scenarios of climate changes, impact on water bodies along the project area has been forecasted by the application of numerical models. Salinity increase trend has been recognized as well as the decrease of water quality parameter values, which present relevant threat for the local agricultural production.
- Primary scope of mitigation measures application is to protect coastal aquifer system from negative effects caused by SWI. Systematic analysis of mitigation measures effectiveness highlights positive effects through laboratory and numerical modeling activities. By implementation of both climate changes and mitigation measures, performed analyses offered detailed insight to time scales of the water quality recovery and its spatial peculiarities.

Figure 24. MoST app dashboard

ABOUT THE PROJECT

Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation (MoST)

CBC Interreg Italy – Croatia 2014.-2020.

Project call: Standard

Priority axis: Safety and resilience

Implementation period: 01/01/2019-30/06/2022

Lead partner: University Padua

Project partners: CNR ISMAR, REGIONE VENETO, CONZORZIO DI BONIFICA ADIGE EUGANEO, UNIST-FGAG, HRVATSKE VODE, DUNEA

Budget: 2.6 mil. EUR

CR partners contacts: Veljko Srzić, Associate professor (veljko.srzic@gradst.hr, UNIST-FGAG); Stjepan Kamber (stjepan.kamber@voda.hr, HRVATSKE VODE); Petar Maleta (pmaleta@dunea.hr; DUNEA)

MoST

Monitoring prodora slane vode u obalne vodonosnike i testiranje pilot projekata za prevenciju prodora soli

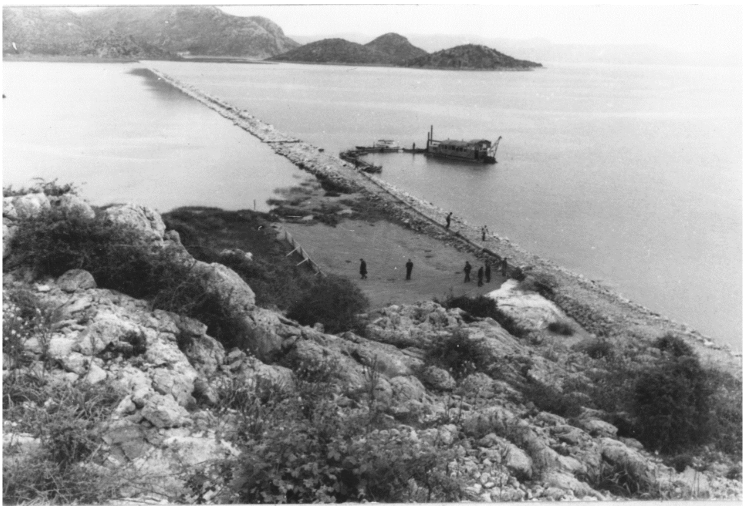
Program prekogranične suradnje

Interreg Italija - Hrvatska 2014.-2020.

O PODRUČJU

Dolina Neretve je važan poljoprivredni kraj u kojemu se pretežno uzgajaju agrumi, (proizvede se 4000 vagona mandarina) zatim slijede lubenice i šljive. Od povrća uzgajaju se rajčice, salata, krastavci, itd. Također značajan je uzgoj maslina koji datira još od Neretvanske kneževine.

Bogato tlo ispresijecano je kanalima kako bi se stvorili uvjeti za uzgoj raznih poljoprivrednih kultura s naglaskom na raznovrsne agrume kao što su limuni, naranče, klementine i ostali. Neretva je prava prijestolnica mandarina, procjenjuje se da je na tom području posađeno oko 1.4 milijuna stabala koji svake godine urode bogatim plodom.



SLIKA 1. FOTOGRAFIJA NA PODRUČJE OBALNOG NASIPA DIGA PRI IZGRADNJI

Neretvansko je područje zapravo najveće promjene doživjelo kroz proteklih nekoliko desetljeća. Prije toga bio je to kraj močvarnih područja i hidrofilne vegetacije koja ih je okruživala, dok su danas te močvare isušene, a zemljište je više prilagođeno uzgoju i obradi plodova.

Ovo izvorno močvarno područje, najintenzivniju preobrazbu doživjelo je od 50 – ih do 80 – ih godina 20. stoljeća kada su započete i u većoj mjeri završene suvremene melioracije. Način na koji su močvare delte Neretve isušivane i privođene kulturama poznat je pod nazivom „jendečenje“ i predstavlja tehniku prokopavanja kanala i čišćenje nanosa iz njih kako bi se dobio materijal za nasipanje vlažnog zemljišta.

U drugoj polovici 20.-og stoljeća započinje provedba istražnih radova u širem području donjeg toka rijeke Neretve unutar teritorija Republike Hrvatske, a s ciljem izgradnje infrastrukture za prenamjenu tog područja. Istražnim radovima obuhvaćene su različite lokacije: Opuzen Ušće, Vidrice, Crepina, Jasenska i Mala Neretva. Već šezdesetih godina prošlog stoljeća kreće se s isušivanjem jezera Modrič i izgradnjom obalnog nasipa Diga koja i danas predstavlja razdjelnicu doline i mora, na potezu od ušća Neretve do ušća Male Neretve, u duljini od oko 1800 m. Potom je izveden sustav kanala i crpnih stanica za odvodnju područja Opuzen Ušće i Vidrice.

Na području Opuzen Ušća kanali konvergiraju ka usisnom bazenu crpne stanice Modrič, koja s instaliranim kapacitetom od 19.6 m^3/s prikupljenu vodu prepumpava u more kod ušća Male Neretve i tako održava povoljne razine podzemnih voda u površinskom vodonosnom sloju. Odvodnja područja Vidrica temelji se na radu crpne stanice Prag. Nešto manjeg kapaciteta u odnosu na crpnu stanicu Modrič, a u skladu s količinom vode u tom području, prepumpava vodu iz područja Vidrica u Malu Neretvu koja dalje teče u more.

Podsustav Mala Neretva inicijalno je zamišljen kao sustav zaštite od poplava kojim se dio poplavnog vala prihvaća i rasterećuje tok Neretve nizvodno od Opuzena. S obzirom na izgrađenost unutar inundacijskog područja, odstupa se od inicijalne uloge i danas Mala Neretva predstavlja retenciju svježe vode prikladne za navodnjavanje ovog područja i područja Crepine. Regulacija Male Neretve vrši se dvama ustavama. Uzvodna ustava s brodskom prevodnicom nalazi se u Opuzenu, 200 m od odvojka Male Neretve iz glavnog toka Neretve. Veći dio godine ustava je zatvorena kako bi se očuvala kakvoća voda Male Neretve. Na samom ušću Male Neretve postavljena je nizvodna ustava koja ima za cilj regulirati razinu vodnog lica Male Neretve i spriječiti unos slane vode uzvodno, čime se osigurava prikladna kakvoća voda Male Neretve za navodnjavanje.

Po izvedbi i puštanju infrastrukture za upravljanje vodama u funkciju dolazi do odstupanja od postojećeg režima voda, ostvaruju se uvjeti za aktivnu intruziju morske vode, čime istovremeno s intenziviranjem poljoprivredne proizvodnje dolazi do potrebe za ulaganjem dodatnih napora u pogledu očuvanja kakvoće vode za navodnjavanje.

Zaslanjivanje voda i tala područja doline Neretve od Opuzena na istoku do mora na zapadu posljedica je složenih procesa koji su uvjetovani vanjskim utjecajima definiranima klimatološkim, meteorološkim, hidrološkim prilikama, varijacijama razine mora i režimima rada sustava navodnjavanja i odvodnje.

CILJEVI PROJEKTA

Glavni ciljevi projekta MoST su: i) povećanje kapaciteta za podizanje razine spremnosti na odgovore na klimatske promjene i njihove učinke, ii) osiguranje međunarodone prepoznatljivosti i kompetitivnosti u rješavanju problema i razumijevanju procesa intruzije morske vode u obalne vodonosnike, iii) kreiranje međunardodnih istraživačkih klastera, iv) provedba istraživanja prilagođenih specifičnostima pilot područja s konačnim ciljem izrade adaptacijskih planova i/ili plan ova prilagodbe klimatskim promjenama.

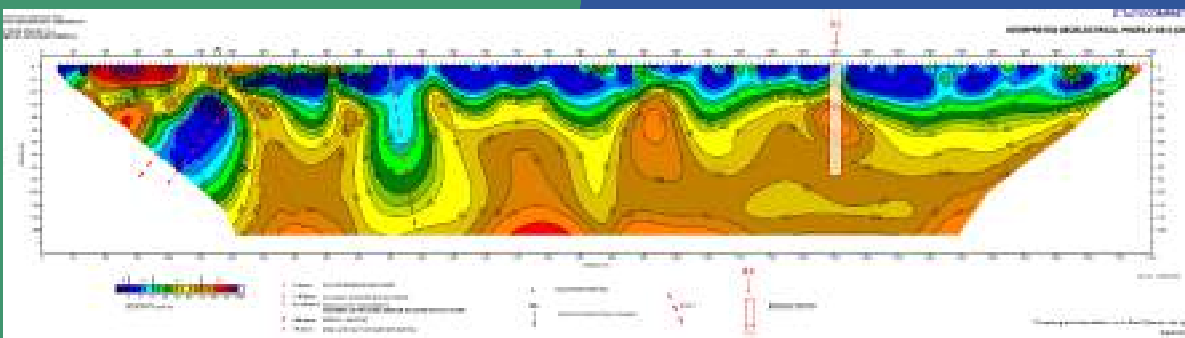
Osiguranje ostvarenja navedenih ciljeva provodi se kroz istraživačke projektne aktivnosti: i) provedba istražnih radova, ii) uspostava sustava monitoringa stanja voda u projektnom području, iii) laboratorijsko modeliranje, iv) numeričko modeliranje.

Po provedbi primarnih istraživačkih aktivnosti pristupa se analizi mitigacijskih mjera i testiranju uspješnosti istih na pilot području iz čega proizlaze smjernice za prilagodbu klimatskim promjenama s ciljem dugoročnog i održivog poboljšanja stanja voda u području.

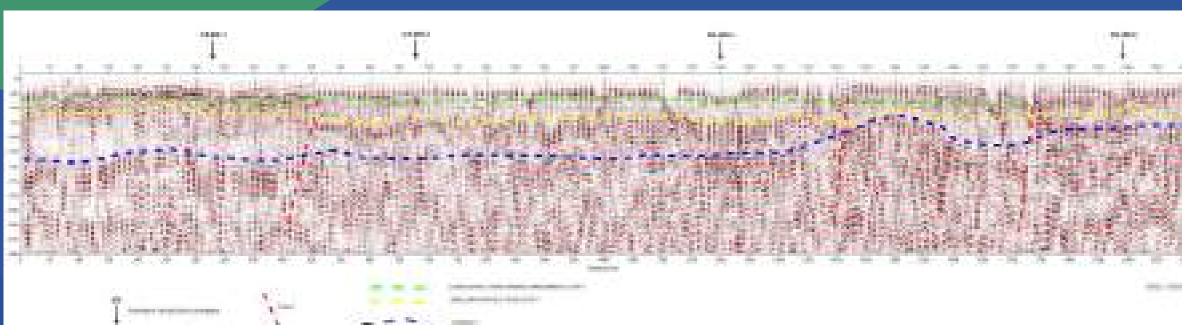
AKTIVNOSTI ISTRAŽNIH RADOVA

U sklopu projektnih aktivnosti proveden je program istražnih radova s ciljem utvrđivanja litološko stratigrafske definicije vodonosnog sustava područja Opuzen Ušće i Vidrice. Programom je obuhvaćen niz terenskih radnji, primjena geoelektrične tomografije, seizmičke refleksije, geoeelektričnih sondi, izvedbe istražnih bušotina, laboratorijska obrada izuzetih uzoraka te primjena geofizičke metode zasnovane na konceptu elektromagnetskog polja (AEM). Kombiniranjem različitih metodoloških pristupa cilj je povećati pouzdanost rezultata i osigurati preduvjete za razvoj numeričkog modela intruzije morske vode u obalni vodonosnik a time i podići kapacitet u predviđanju stanja slanosti voda u projektnom području. Tomografskim profilima utvrđeno je polje otpora koje se interpretira uzimajući u obzir svojstva materija vodonosnika i podzemnih voda, do dubine od 200 m gdje se sa sigurnošću zadire u stijensku masu. Zone prijelaza iz jedne lito stratigrafske jedinice u drugu utvrđene su primjenom seizmičke refleksije dok je jezgra bušotine korištena kao podatak prvog reda za kalibraciju rezultata geofizičkih metoda.

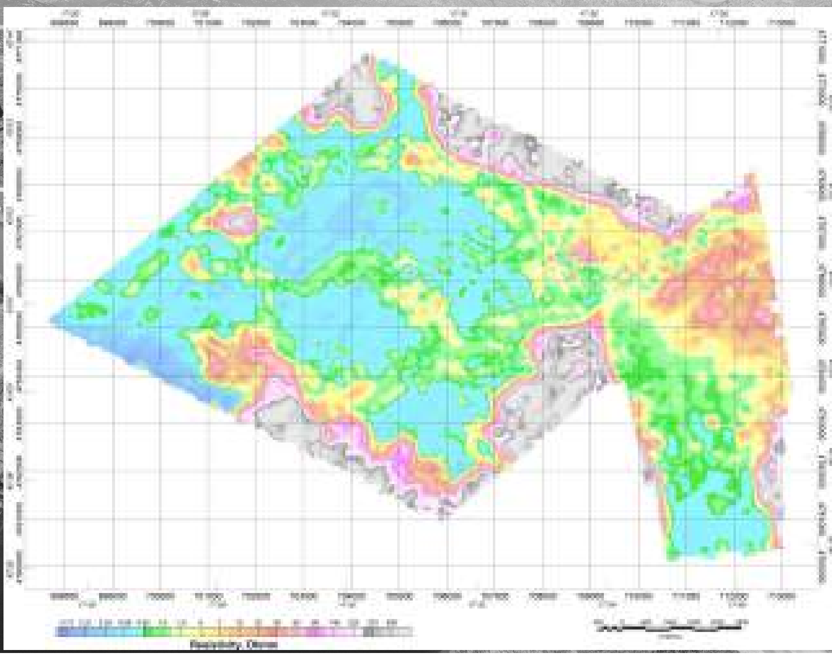
Za razliku od konvencionalnih geofizičkih metoda, AEM je po prvi put primijenjena na projektnom području i jedina je metoda koja omogućava prostorno kontinuirani opis otpora na projektnom području.



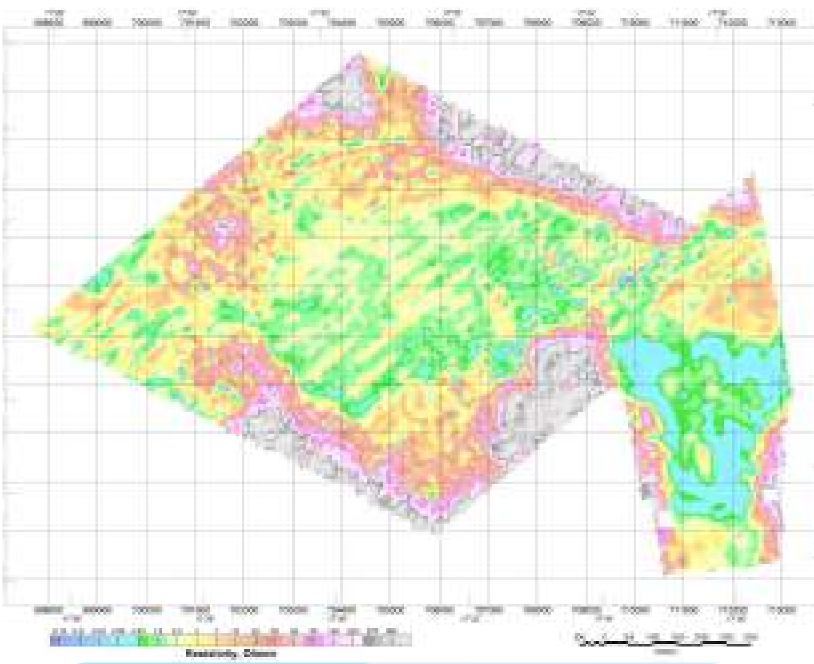
Slika 2. Profil polja otpora dobiven primjenom geoelektrične tomografije na lokaciji nasipa Diga



Slika 3. Interpretacija rezultata seizmičke refleksije na istražnom profilu Crepina

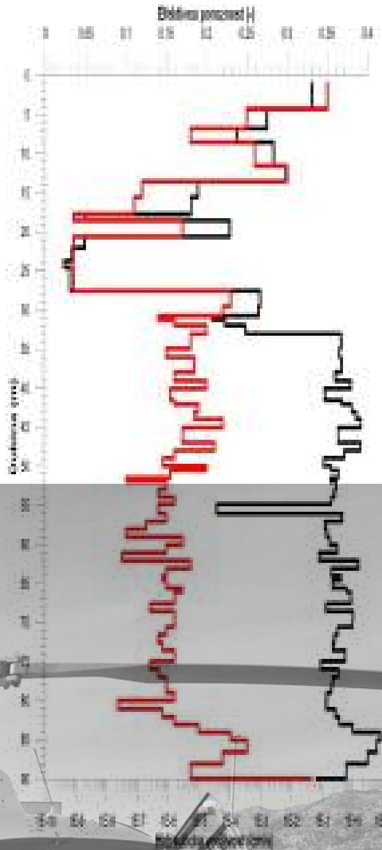


Slika 4. Polje otpora na dubini 20 m dobiveno interpretacijom primjene AEM



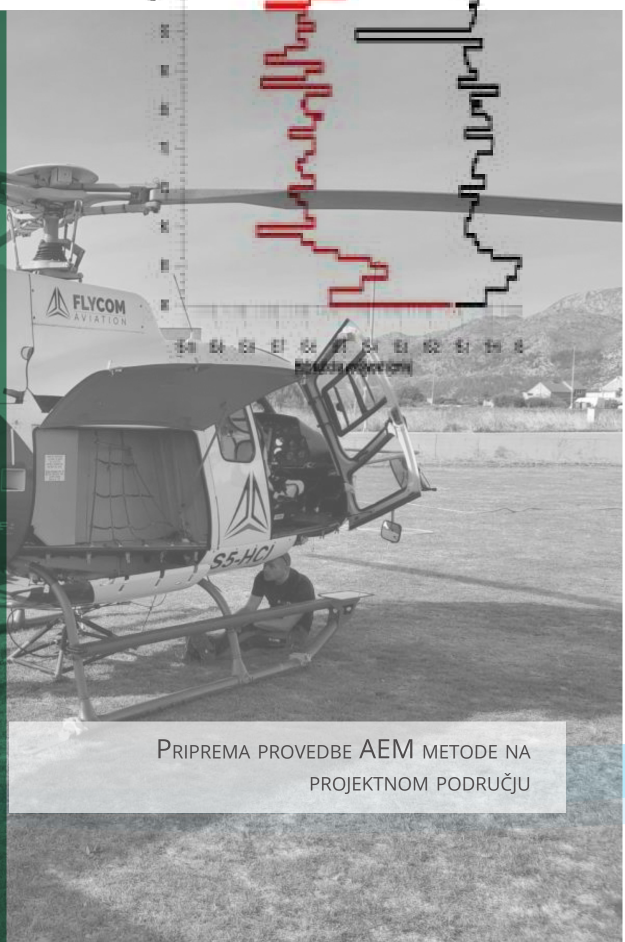
Slika 5. Polje otpora na dubini 50 m dobiveno interpretacijom primjene AEM

Slika 6. Presjek jezgre istražne bušotine B-2 na profiilu nasipa Diga



Slika 7. Hidraulička vodljivost i efektivna poroznost utvrđene iz jezgre istražne bušotine B-2 u laboratorijskim uvjetima

Analizom prikupljenih podataka i interpretacijom rezultata istražnih radova utvrđen je raspored litoloških jedinica. Površinski vodonosnik prosječne je debljine 7-10 m, uglavnom je sačinjen od dominantno pjeskovitog materijala s prisustvom proslojaka gline. Ispod ovog sloja evidentiran je kompaktan glineni sloj čija se debljina povećava od istoka ka zapadu i na profilu Diga iznosi oko 20 m. Ispod glinenog sloja nalazi se vodosnosik pod tlakom, široke granulacije i većeg stupnja međuzrnate zaglinjenosti. Čvrsta stijena u projektnom području detektirana je na dubinama do 180 m.



Priprema provedbe AEM metode na projektnom području

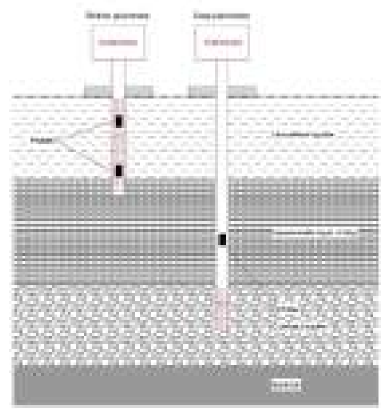
European Regional Development Fund

Infrastruktura sustava monitoringa na lokaciji usisnog bazena crpne stanice Modrič

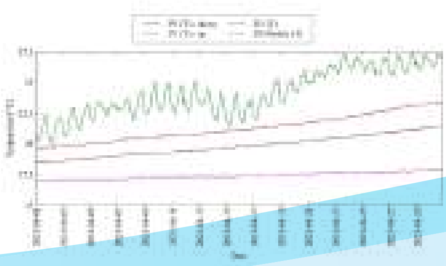
AKTIVNOSTI MONITORINGA

Za potrebe projekta uspostavljen je sustav kontinuiranog monitoringa stanja površinskih i podzemnih voda u realnom vremenu. Svi podaci prikupljaju se na server i dostupni su putem MoST mobilne aplikacije.

U plitkom vodonosnom sloju implementirane su po dvije sonde kako bi se osigurao kapacitet praćenja stanja voda u uvjetima izražene stratifikacije slanosti. Razvojem, implementacijom i poboljšanjima sustava omogućene su analize procesa koji utječu na stanje voda, njihova dinamička svojstva i prostornu varijabilnost svojstava.

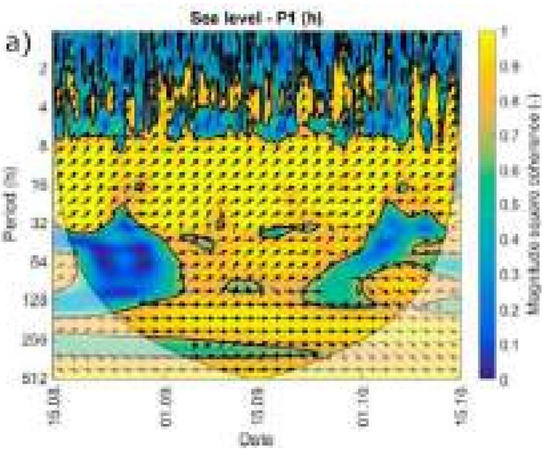


Slika 8. Shematski prikaz rješenja mjerne infrastrukture

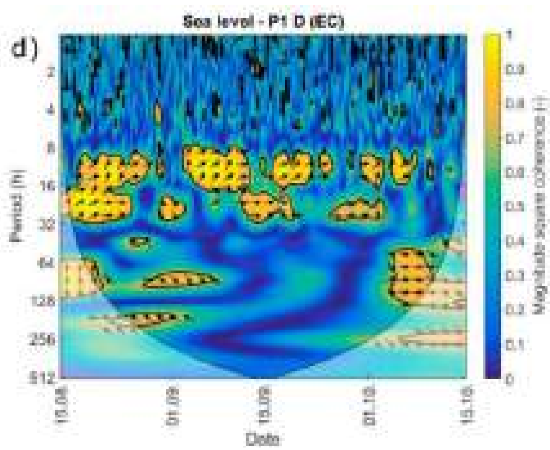


Slika 9. Uvid u mjerene podatke o stanju voda

Slika 10. Unutrašnjost mjerne kutije na pijezometru



Slika 11. Prikaz koherencije za mjerene varijable razine mora i razine podzemnih voda



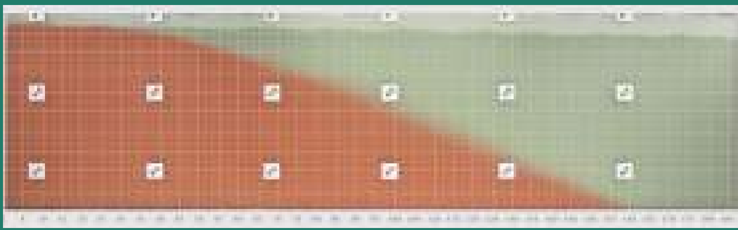
Slika 12. Prikaz koherencije za mjerene varijable razine mora i električne vodljivosti podzemnih voda

LABORATORIJSKO MODELIRANJE

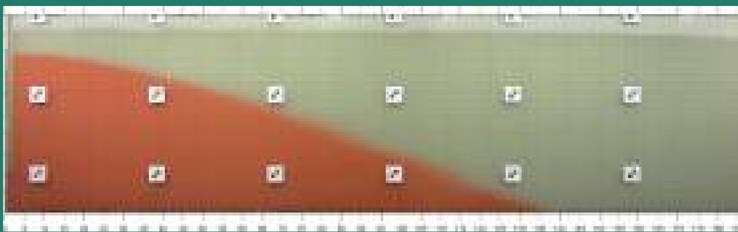
Laboratorijskim modelom modelirani su uvjeti slanosti u postojećem stanju projektnog područja. Osim toga ispitan je utjecaj klimatskih promjena, primarno kroz predviđena podizanja srednje razine mora kao i utjecaj na stanje slanosti voda u području od interesa.

U laboratorijskim uvjetima testirana je uspješnost primjene mitigacijskih mjera za zaštitu od štetnog djelovanja morske vode, u sklopu čega su implementirana rješenja poput injekcijske zavjese na profilu Diga i izvedbu kanala za navodnjavanje duž lijeve obale rijeke Neretve, od buduće barijere do mora.

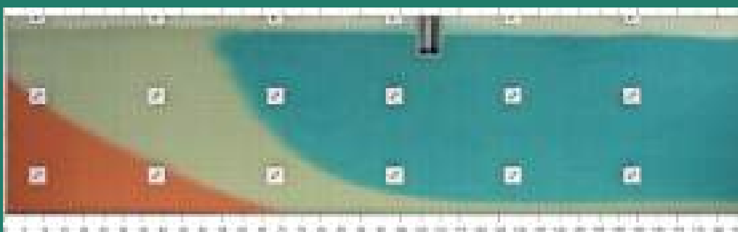
S obzirom kako su na projektnom području detektirni uvjeti aktivne intruzije morske vode, barijera na Digi nije se pokazala kao efektivna mitigacijska mjera. S druge strane, kanal za navodnjavanje u smislu funkcionalnosti i poboljšanja voda klasificiran je kao izrazito uspješna mjera zaštite te je u sklopu projekta dodatno razrađen postupak izbora parametara kanala.



Slika 13. Prikaz rezultata laboratorijskog modela aktivne intruzije morske vode u postojećem stanju



Slika 14. Prikaz rezultata laboratorijskog modela aktivne intruzije morske vode uz primjenu parcijalno uronjene nepropusne zavjese



Slika 15. Prikaz rezultata laboratorijskog modela aktivne intruzije morske vode uz primjenu kanala za navodnjavanje

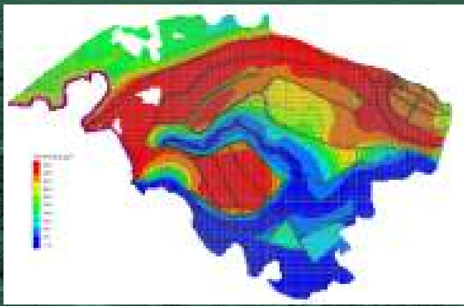
NUMERIČKO MODELIRANJE

Za potrebe procjene stanja voda u uvjetima klimatskih promjena i mitigacijskih mjera unutra GMS okruženja implementiran je numerički model kojim se simuliraju prostorno vremenska svojstva polja slanosti voda na projektnom području u uvjetima dvostruke gustoće.

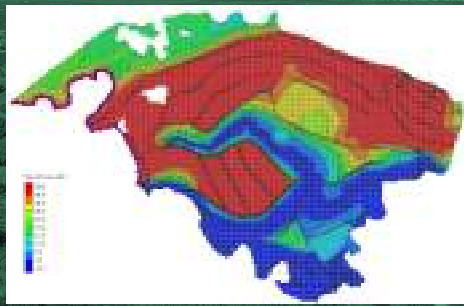
Za prikladno odabrane rubne i početne uvjete, postupkom kalibracije odabrani su parametri modela u postojećem stanju nakon čega je provedena validacija modela podacima iz sustava monitoringa.

Prognoza povećanja srednje razine mora za 84 cm (IPCC; RCP8.5) ukazuje na vidljivo odstupanje od postojećeg stanja slanosti i dodatnu ugrozu poljoprivredne proizvodnje.

Implementacijom kanala za navodnjavanje u prostorni obuhvat lijeve obale rijeke Neretve nizvodno od lokacije buduće pregrade, modelski rezultati ukazuju na značajno i dugoročno poboljšanje stanja voda u obuhvatu čime se ukazuje na prikladnost takvog rješenja i potrebu za daljnjom razradom tehničkog rješenja.



Slika 16. Prikaz polja koncentracije soli u plitkom vodonosnom sloju u postojećem stanju

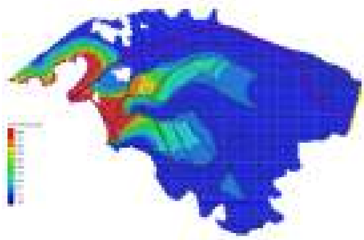


Slika 17. Prikaz polja koncentracije soli u plitkom vodonosnom sloju za slučaj povećanja srednje razine mora od 84 cm

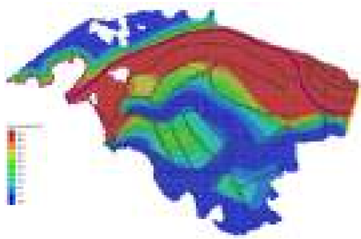
MITIGACIJSKE MJERE I UČINKOVITOST

U sklopu projekta testiran je veći broj mitigacijskih mjera koje su se odnosile na upravljačke i infrastrukturne mjere koje potencijalno imaju za cilj poboljšanje stanja voda i smanjenje intenziteta unosa morske vode o obalni vodonosni sustav delte rijeke Neretve.
Analizom kišnog i sušnog razdoblja utvrđeni su različiti koridori unosa morske vode. Za razliku od kišnog razdoblja kada se unos morske vode dominantno ostvaruje kroz obalni nasip Diga u duljini 2.0 km, u sušnom razdoblju detektira se dominacija morske vode u koritu rijeke Neretve čime rijeka postaje izvor slane vode.

Odabir koncepta zaštite projektnog područja od štetnog djelovanja morske vode zasniva se na analizama postojećeg stanja. Po izvedbi injekcijske zavjese na Digi pospješuje se smanjenje unosa morske vode u obalni vodonosnik. S obzirom na činjenicu kako je proces intruzije morske vode u projektnom području okarakteriziran kao aktivan, nužno je intervenirati u lijevu obalu rijeke. Učinak ovakve intervencije drastično pospješuje stanje voda u projektnom obuhvatu i predstavlja sustavno i jedinstveno rješenje zaštite od štetnog djelovanja mora.

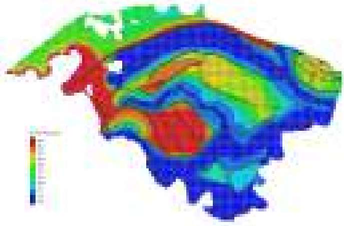


Slika 18. Prikaz polja koncentracije soli u plitkom vodonosnom sloju u postojećem stanju tijekom kišnog razdoblja

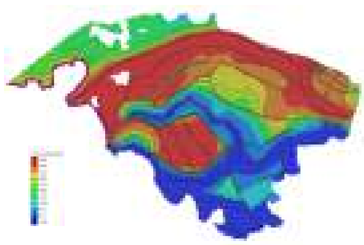


Slika 19. Prikaz polja koncentracije soli u plitkom vodonosnom sloju u postojećem stanju tijekom sušnog perioda

Slika 20. Prikaz polja koncentracije soli u plitkom vodonosnom sloju za slučaju implementacije barijere u Neretvi i kanala za navodnjavanje duž lijeve obale rijeke Neretve



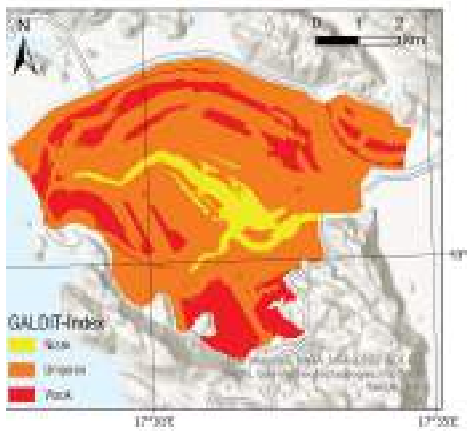
Slika 21. Prikaz polja koncentracije soli u plitkom vodonosnom sloju za slučaju implementacije injekcijske zavjese duž nasipa Diga



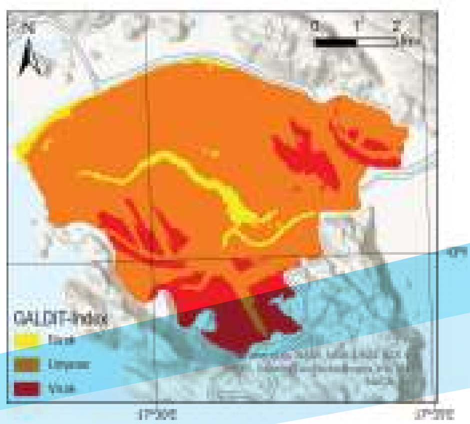
ZAKLJUČCI I SMJERNICE

Provedbom projektnih aktivnosti projekta MoST podignuta je razina znanja i razumijevanja o procesima koji utječu na stanje slanosti površinskih i podzemnih voda u obuhvatu projektnog područja, te su osigurane podloge i specifična znanja koja doprinose podizanju razine spremnosti i odgovora na klimatske promjene i utjecaj istih na stanje voda u vodonosnom sustavu delte Neretve.

- Uspostavljen je i implementiran monitoring stanja površinskih i podzemnih voda u realnom vremenu. Podaci prikupljeni ovim sustavom monitoringa dostupni su putem web i mobilne aplikacije MoST i mogu poslužiti u svakodnevnom praćenju stanja voda kao i u planiranju mjere zaštite od štetnog djelovanja morske vode u bližoj i daljoj budućnosti.
- Utvrđena je lito-stratigrafska definicija obalnog vodonosnog sustava projektnog područja. U sklopu definicije utvrđeni su prostorni rasporedi slojeva, karakteristične vrijednosti hidrauličke vodljivosti i efektivne poroznosti te prostorna heterogenost istih.



Slika 22. Prikaz prostorne razdiobe ranjivosti u postojećem stanju



Slika 23. Prikaz prostorne razdiobe ranjivosti za projekcije klimatskih promjene uz implementaciju mitigacijskih mjera

• Prognoznim modelskim pristupom kvantificiran je utjecaj klimatskih promjena na stanje voda i svojstva slanosti vodnih tijela. Neupitna je prisutnost daljnjeg trenda smanjenja kvalitete vode a time i povećanje ugroze poljoprivredne proizvodnje.

• Mitigacijske mjere imaju za cilj zaštitu područja od štetnog djelovanja morske vode i očuvanje te poboljšanje kakvoće voda u projektnom području. Predložene mitigacijske mjere testirane su i ispitane u laboratorijski uvjetima te su uspješno implementirane u numerički model na skali projektnog područja. Provedenim analizama utvrđena je uspješnost mitigacijskih mjera u očuvanju kakvoće voda za potrebe navodnjavanja.

Slika 24. Sučelje MoST aplikacije

O PROJEKTU

Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation (MoST)
Program: Prekogranična suradnja Interreg Italija - Hrvatska 2014.-2020.
Projektni poziv: Standard
Prioritetna os: Sigurnost i otpornost
Implementacija: 01/01/2019-30/06/2022
Vodeći partner: SVEUČILIŠTE U PADOVI
Projekti partneri: CNR ISMAR, REGIONE VENETO, CONZORZIO DI BONIFICA ADIGE EUGANEO, UNIST-FGAG, HRVATSKE VODE, DUNEA
Vrijednost projekta: 2.6 mil. EUR
Kontakt HR partneri: Izv.prof.dr.sc. Veljko Srzić (veljko.srzic@gradst.hr, UNIST-FGAG); Stjepan Kamber (stjepan.kamber@voda.hr, HRVATSKE VODE); Petar Maleta (pmaleta@dunea.hr; DUNEA)