Zajednica izvršitelja

Naručitelj

Krajnji korisnik

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – STUDIJA POREČ

IZVJEŠĆE 17

Izvješće o izvršenoj edukaciji

ožujak 2022

Sažetak

Izvješće br. 17 predstavlja aktivnosti glede edukacije djelatnika krajnjeg korisnika Odvodnje Poreč. Edukacija je provedena u 4 navrata u Poreč, svaki u trajanju od 3 dana i to:

1. Modeliranje sustava odvodnje (Proning DHI, Hrvatska)
2. Modeliranje mora (IMDC, Belgija)
3. Uzorkovanje i eksperimentalne metode (PBF, Hrvatska)
4. Modeliranje UPOVa (ASM Design, Nizozemska)

Neophodne licence za korištenje potrebnih softwera su osigurane. Neophodni softweri za provođenje edukacije, te rad djelatnika krajnjeg korisnika nakon okončanja Studije Poreč su instalirani na računalima krajnjeg korisnika u Poreču. Edukacija je izvršena uspješno.

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 17 – dio 1/4

EDUKACIJA DJELATNIKA: MODELIRANJE SUSTAVA ODVODNJE

Studeni 2020

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IZVJEŠĆE 17 – dio 1/4

EDUKACIJA DJELATNIKA: MODELIRANJE SUSTAVA ODVODNJE

22 studeni 2022

17 studeni 2020

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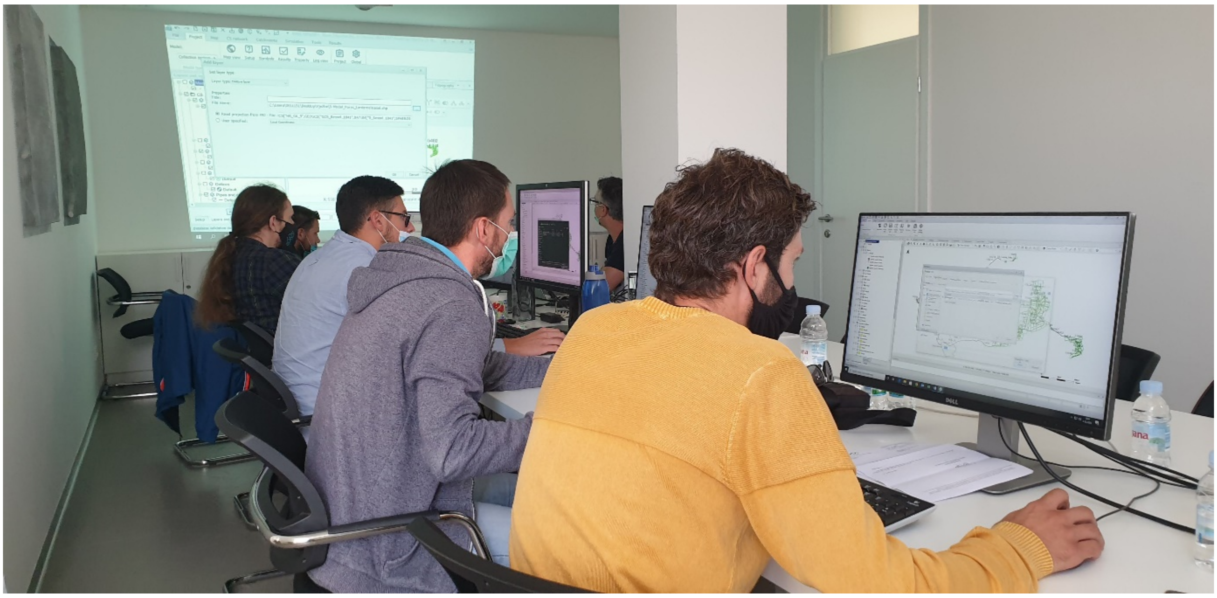
Ovlaštenik Zajednice izvršitelja
Proning DHI d.o.o.

IHE Delft

Studija ocjene i praćenja učinkovitosti provedbe projekta izgradnje kanalizacijske mreže i analiza učinkovitosti rada uređaja za pročišćavanje otpadnih voda u gradu Poreču – Studija Poreč

MODELIRANJE SUSTAVA ODVODNJE

IZVJEŠĆE 17 dio 1/4: Edukacija djelatnika krajnjeg korisnika modela



studeni 2020.

SADRŽAJ

1 UVOD

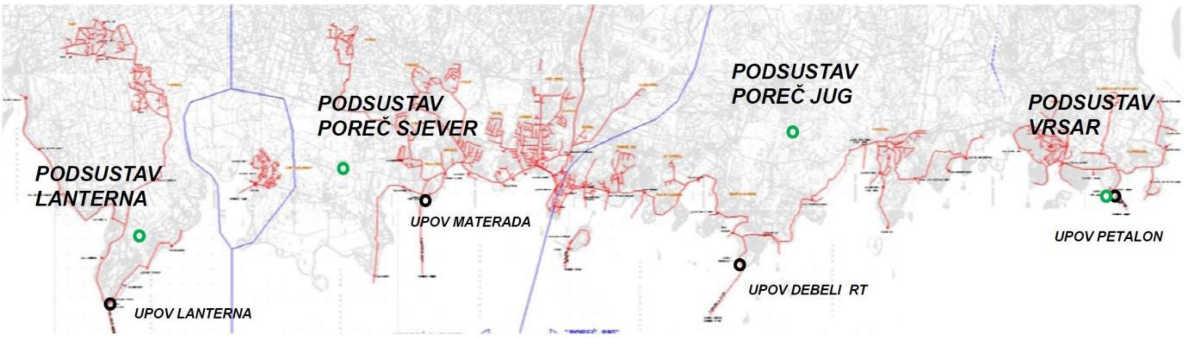
Ovo izvješće nastavlja se na prethodne aktivnosti na projektu Poreč u dijelu koji se odnosi na izradu hidrološko-hidrauličkih matematičkih modela sustava odvodnje Poreč. Nakon završene izrade i kalibracije modela odvodnje sustava, uz predaju modela na korištenje krajnjem korisniku provedena je edukacija djelatnika korisnika u trajanju od 3 radna dana – 7.10.2020.-9.10.2020. godine.

1.1 ZADATAK

Nastavno se ukratko prikazuju obaveze iz Projektnog zadatka koje se odnose na modeliranje sustava odvodnje Poreč.

Očekivani rezultati projekta su:

- Primjenom matematičkog modeliranja biti će moguće predvidjeti funkcioniranje sustava odvodnje otpadnih voda grada Poreča kako za postojeće stanje, tako i za razne scenarije tijekom koji su mogući u budućnosti.



Slika 1 Zemljopisno područje projekta - shematski prikaz sustava sanitarne kanalizacije sa četiri pripadajuća UPOV-a obuhvaćena Studijom Poreč

Studija Poreč sastoji se od tri komplementarna i povezana dijela:

1. **Modeliranje sustava odvodnje grada Poreča – predmet ovog izvješća**
2. Modeliranje četiri nova UPOV-a (Modeliranje UPOV-a);
3. Modeliranje mora na širem području grada i odabranih plaža Poreča (Modeliranje mora).

Ovim Projektnim zadatkom podrazumijeva se da će:

- Svaki od četiri sustava odvodnje biti modelirani kao poseban sustav povezan s pripadajućim UPOV-om tog sustava;
- Modeli biti međusobno povezani tako da izlaz jednog modela posluži kao ulaz u slijedeći model u nizu: sustav odvodnje - UPOV – more, tj. da će rezultati pojedinačnog modela biti integrirani u rezultat koji oslikava situaciju (scenarij) na cijelom području obuhvaćenom Studijom Poreč, te istovremeno omogućuje razmatranje svakog sustava u cijelosti i razdvojeno.

Modeliranje sustava odvodnje

Jedna od vrlo važnih početnih aktivnosti na projektu je snimanje postojećeg stanja, te novog stanja s priključenjem 28 novih naselja i 6.300 stanovnika na području grada Poreča i arhiviranje prikupljenih podataka u GIS software-u je dio Projekta Poreč. Podaci o sustavu odvodnje u GIS-u će biti dostupni Izvršitelju.
Dio Modeliranje sustava odvodnje će objediniti informacije i o postojećem sustavu odvodnje (nerekonstruiran i rekonstruiran) i o proširenju sustava. Uključivat će minimalno 4 scenarija kako je sažeto prikazano u Tablica 1 Scenariji studije Poreč, mjerodavne za opis situacije ljeti i zimi, te za minimalni i maksimalni protok (i opterećenje) u sustavu odvodnje i to u okolnostima određenim neposredno nakon kompletiranja Projekta Poreč (po planu iz PZ - 2017.) i predviđenim na kraju projektnog perioda (2040.).

Tablica 1 Scenariji studije Poreč

Br.	Sezona		Opterećenje	Kanalizacija	UPOVi	More	Komentar
LJ1	Ljeto	PUPE	Maksimalno	■	■	x	Nema potrebe za modeliranjem mora zbog 100% PUPE
LJ2		IPE				■	Manji utjecaj na kakvoću mora zbog učinkovitosti UPOV-a s ultrafiltracijskom MBR tehnologijom
LJ3		ISE			x	■	Veći utjecaj na kakvoću mora (naročito na odabranim plažama) zbog (privremenog) odsustva tretmana i maksimalnog opterećenja. Potrebno je izraditi pod-scenarij dobre izmiješanosti mora, te izražene stratifikacije morskog stupca (početak ljeta i kraj ljeta, respektivno)
LJ4		PUPE/IPE	Minimalno	■	■	x	Nema potrebe za modeliranjem mora zbog 100% PUPE ili učinkovitosti MBR tehnologije
Z1	Zima	PUPE	Maksimalno	■	■	x	Nema potrebe za modeliranjem mora zbog 100% PUPE
Z2		IPE				■	Manji utjecaj na kakvoću mora zbog učinkovitosti UPOV-a s ultrafiltracijskom MBR tehnologijom
Z3		ISE			x	■	Srednji utjecaj na kakvoću mora zbog manjeg opterećenja i odsustva kupanja na plažama zimi
Z4		PUPE/IPE	Minimalno	■	■	x	Nema potrebe za modeliranjem mora zbog 100% PUPE ili učinkovitosti MBR tehnologije

U nastavku se navode glavne aktivnosti kako su definirane projektnim zadatkom. Rad na izradi matematičkih modela sustava odvodnje Poreča uglavnom prati grupe aktivnosti kako su u nastavku definirane.

1. Prikupljanje dostupnih podataka potrebnih za modeliranje svakog od četiri sustava odvodnje kao sto su: informacije o sustavu odvodnje u GIS-u (trasa i lokacija cijevi, eventualnih rasterećenja protok u cijevi, pad i promjer cijevi, materijal cijevi, lokaciju revizionih okana, kote dna cijevi, okana i terena, itd), informacije iz bilo kojih drugog izvora (projektna dokumentacije, itd), model terena bilo u digitalnom (DTM) ili nekom drugom upotrebljivom obliku (karte itd.), količine otpadne vode, koncentracije onečišćenja od značaja u sirovoj

otpadnoj vodi, informacije o postojećim i novim crpnim stanicama (lokacija, režim rada, kapacitet, postojeća/nova funkcija u postojećem/obnovljenom/proširenom sustavu odvodnje, vrsta stanice npr. za dizanje ili tlačno crpljenje, informacije o postojećim podmorskim ispustima (duljina, promjer cijevi, kota dna mora na lokaciji ispusta itd.), podaci o infiltraciji, hidrološki i klimatski podaci i bilo koji drugi podaci koje Izvršitelj smatra bitnim za izradu Studije Poreč.

2. Prikupljanje dijela podataka glede protoka i kakvoće otpadne vode u sustavu grada Poreča Izvršitelj je obvezan učiniti tijekom projekta i to u dva navrata: jednom tijekom rekonstrukcije i proširenja sustave odvodnje (u svrhu prikupljanja stvarnih podataka i inicijalne kalibracije i validacije modela), te drugi put nakon sto su UPOV-i pušteni u rad i postigli projektiranu učinkovitost.

   Kampanja uzorkovanja treba uključiti sva četiri sustava na najmanje jednoj mjerodavnoj lokaciji u trajanju od 7 dana u nizu, jednom u zimskoj sezoni i jednom u ljetnoj sezoni (zahtjev za oba navrata). Uzorci moraju biti 1h (ili 2h) kompozitni, što znači 24 ili 12 uzoraka po danu za svaki od 7 dana na svakom sustavu i u zimskom i ljetnom periodu. Parametri koji će se odrediti iz uzoraka moraju zadovoljiti potrebe za karakterizaciju otpadnih voda potrebnih za primjenu modela za modeliranje sustava odvodnje, te modela za modeliranje UPOV-a.

   Izvršitelj će prikupiti i podatke o protoku (srednja satna vrijednost za period od 24 h) na mjerodavnim lokacijama u svakom sustavu odvodnje i to u trajanju od najmanje 7 dana kontinuirano, zimi i ljeti, te u dva navrata: tijekom rekonstrukcije i izgradnje i nakon puštanja u rad UPOV-a. Iako su sustavi odvodnje razdjelni, te je predmet Studije Poreč sanitarni dio tih razdjelnih sustava, poželjno je izvršiti uzorkovanje tijekom perioda bez (značajnih) oborina (period suhog vremena). U slučaju da prikupljanje podataka od strane Izvršitelja zbog bilo kojeg opravdanog razloga nije moguće, Izvršitelj se u tom slučaju može osloniti isključivo na informacije o protoku prikupljenih iz drugih izvora (projektna dokumentacija, postojeći zapisi protoka ako postoje itd.). Naručitelj se obvezuje da će osigurati Izvršitelju pristup mjerodavnim lokacijama za uzorkovanje i mjerenje protoka tijekom trajanja kampanje uzorkovanja Studije Poreč. Naručitelj ne snosi odgovornost za sigurnost osoblja Izvršitelja, te eventualno uporabljene opreme Izvršitelja (npr. automatski uzorkivači, mjerači protoka, mjerni instrumenti itd.) tijekom trajanja uzorkovanja i Studije Poreč. Detaljnu metodologiju prikupljanja i obrade podataka neophodnih za ovaj dio studije Izvršitelj će prikazati u izvješću o zatečenom stanju u projektu.

3. Na osnovu prikupljenih podataka Izvršitelj će pripremiti set podataka koji će se koristiti za svrhu modeliranja sustava odvodnje i kasnije djelomično za modeliranje UPOV-a. Izrada hidrauličkog modela kanalizacijske mreže pomoću odabranog programskog paketa treba biti na bazi prikupljenih i odabranih podataka. Poželjni programski paket je iz obitelji softvera DHI MIKE URBAN koji je primijenjen u velikom broju projekata u Republici Hrvatskoj. Ovaj model – DHI MIKE URBQN će konzultant i koristiti u proračunima
   Model će se uspostaviti na temelju podataka i informacija koje pruži Naručitelj i prikupi Izvršitelj. Model treba uzeti u obzir geometriju kanalizacijskih mreža i površinski materijal i materijal tla, najviše zbog procjene infiltracije. U model trebaju biti uključene sve hidrotehničke građevine, uključujući crpke i njihove karakteristike.

4. Izvođenje na modelu utemeljenih proračuna svih četiriju sustava kanalizacijske mreže za scenarije nabrojane u Tablica 1 Scenariji studije Poreč i koristeći podatke o postojećem stanju.

5. Kalibracija i validacija rezultata sva četiri modela na temelju dva odabrana razdoblja rada, jedan ljeti i jedan zimi. Ovaj dio zadatka u idealnom slučaju bi trebalo provesti nakon završetka rekonstrukcije i proširenja kanalizacijskog sustava (Projekt Poreč). Međutim, budući da proširenje donosi povećanje od 6.300 korisnika što je u odnosu na predviđeni kapacitet sustava od 137.500 korisnika (ekvivalent stanovnika) relativno skroman doprinos glede protoka i opterećenja, kalibracija i validacija modela se može zasnovati na kampanji uzorkovanja koju Izvršitelj može planirati tijekom rekonstrukcije i proširenja sustava odvodnje, te učiniti dodatnu validacije koristeći podatke koji će postati dostupni tijekom prikupljanja podataka tijekom rada UPOV-a (vidi dio 2 Studije Poreč). Isto tako, Izvršitelj će za svaki od četiri osnovna scenarija prikazana u tablici 1 izvršiti na modelu utemeljene proračune svih četiriju sustava kanalizacijske mreže i za situaciju predviđenu na kraju vijeka projekta (2040.g.)

6. Edukacija djelatnika Krajnjeg korisnika i Naručitelja o modelima za modeliranje sustave odvodnje, te korištenju odabranog modela kako bi isti mogli samostalno koristiti modele razvijene u sklopu ovog dijela projekta tijekom, a naročito nakon završetka Projekta Poreč i Studije Poreč. Edukacija treba uključiti suvremene metode i materijale, a trajati će najmanje 3 (poželjno 5) dana na teritoriju Republike Hrvatske. Jezik edukacije će biti hrvatski

7. Izrada opsežnih izvješća koja uključuju opis aktivnosti i rezultata proizašlih iz gore opisanih zadataka je obveza Izvršitelja i to na hrvatskom jeziku.

Razvoj hidrauličkog modela svakog od četiri sustava odvodnje će biti u tri osnovne faze (zbog provedbe projekta Poreč, Projektnim zadatkom predviđene faze A- B su objedinjene).

A. Model koji će obuhvatiti stanje kakvo će biti u momentu prikupljanja podataka u početnom dijelu Studije Poreč. U ovom periodu očekuje se da projekt rekonstrukcije i proširenja sustave odvodnje neće biti kompletiran, te će zatečeno stanje biti slično sadašnjem stanju (stanju u trenutku objave ovog javnog natječaja za Studiju Poreč). Kalibracija i validacija modela će se izvršiti s podacima važećim za ovaj period. Ovaj će model prikazati polazne uvjete na temelju kojih će se uspoređivati kasniji modeli. Izvršitelj treba razviti inicijalni model na temelju dobivenih podataka o trenutnoj potrošnji vode i rasporedu potrošača. Izvršitelj treba predstaviti rezultate za 24-satno razdoblje koje predstavlja standardnu dnevnu varijaciju. Inicijalni model će se razviti kako bi se identificirali mogući problemi sa stabilnošću modela i trebalo bi provesti jednostavnu kontrolu kako bi se osiguralo da je očuvana bilanca količina (protoka). Budući da će u tom razdoblju trajati građenje, očekuje se da će biti moguće validirati i kalibrirati inicijalni model koristeći podatke iz kampanje uzorkovanja u zimskom i ljetnom periodu u periodu radova na sustavima odvodnje.
B. Model koji će obuhvatiti stanje nakon kompletiranja dijela Projekta Poreč koji se odnosi na izgradnju sustava odvodnje. Za simulaciju će se iskoristiti podaci iz faze A. Postoji mogućnost da s obzirom na dinamiku izvedbe Projekta Poreč faze A i B postanu jedna faza, tj. da možda i neće biti značajne razlike između faze A i B u vrijeme provođenja ovog dijela Studije Poreč. Model bi trebalo proširiti pomoću tehničkih nacrta i GIS informacija za proširen i rekonstruiran sustav. Model će uključivati dodatne kućne priključke iz 28 naselja (6.300 korisnika). Izvršitelj treba provesti ispitivanje kako bi, prema potrebi, modificirao model, temeljem usporedbe izvedenog stanja s projektom i podacima iz GIS-a. Pored toga, na temelju podataka o oborinama i otjecanju odredit će se da li su sustavi zaista razdjelni kako se navodi i imaju li oborine utjecaj na količinu vode u sustavima. Ako se otkrije takav značajan utjecaj, struktura modela će se izmijeniti kako bi odrazila te činjenice. Izvršitelj je dužan ocijeniti utjecaj infiltracije u sustav odvodnje.
C. Kalibrirani i verificirani model iz točke B će se koristiti za analizu scenarija iz tablice 1.

Izvršitelj treba razviti model koji će zadovoljavajuće opisati sadašnju situaciju, situaciju nakon kompletiranja Projekta Poreč, te situaciju pri kraju vijeka projekta 2040. godine.

D. Model iz točke B(C) će se iskoristiti za dodatnu validaciju stanje nakon kompletiranja Projekta Poreč, odnosno njegovog dijela koji se odnosi na kompletiranje i puštanje u rad UPOV-a. Validacija modela će se izvršiti s novim podacima važećim za ovaj period, idealno izmjerenim neposredno nakon što UPOV-i dostignu stabilan i zadovoljavajući rad. Ponovna analiza scenarija iz tablice 1. će se ponoviti samo u slučaju da ova sekundarna validacija bude zahtijevala značajnu kalibraciju modela.

Izvršitelj će proizvesti sljedeće rezultate:

- Izvješća o prikupljenim podacima i pripremi podataka za modeliranje sustave odvodnje. Ova izvješća će obuhvatiti hidrograme protoka na mjernim/razmatranim lokacijama i profile koncentracije mjerenih parametara koji predstavljaju 24-satni ciklus tijekom perioda od najmanje 7 dana u kontinuitetu za svaki od četiri sustava odvodnje u zimskom i ljetnom periodu i to za sadašnju situaciju, situaciju nakon kompletiranja Projekta Poreč, te situaciju za kraj projektnog perioda 2040. godine kako je prikazano u Tablici 1.
- Hidrauličke sheme modela u odgovarajućem digitalnom obliku koji će pored Izvršitelja i ciljane skupine moći koristiti tijekom i nakon Studije Poreč.
- Rezultate simulacija modelom za sve scenarije navedene u tablici 1., te eventualno moguće dodatne scenarije po izboru Izvršitelja s opisom dobivenih rezultata.
- Komparativnu analizu dobivenih rezultata za svaki scenarij uključujući minimalne i maksimalne protoke glede sadašnje situacije, situacije nakon kompletiranja Projekta Poreč, te situacije pred kraj vijeka projekta 2040. godine.
- Edukacija tima ciljanih skupina o modeliranju sustava otpadnih voda.

2 PRIMIJENJENA OBUKA

Kako bi se osigurala održivost primijenjene tehnologije u institucijama korisnika, odnosno kako bi se prenijelo znanje o matematičkom modeliranju provodi se institucionalno jačanje korisnika, odnosno primijenjena obuka. Obuka se sastoji od radionice koja traje tri radna dana, koju provodi tim konzultanta koji je sudjelovao na izgradnji matematičkog modela.

Aktivnosti obuke usmjerene su na prenošenje sveobuhvatnog teorijskog i praktičnog znanja, kao i pripremu operativnog osoblja za izazove s kojima će se suočavati u budućnosti kroz rad na primjeni modela. Kroz radionicu djelatnici razvijaju svoje vještine u hidrološko-hidrauličkom modeliranju.

Važno je prepoznati primijenjenu obuku u dugoročnom uspjehu projekta kroz koji se očekuje da djelatnici Korisnika samostalno rade na modelu nakon završetka projekta. Aktivno sudjelovanje sudionika tijekom cjelokupne provedbe projekta kroz učenje radeći zajedno s osobljem konzultanta osigurat će učinkovito usvajanje novih znanja i vještina.

Prije održavanja svake radionice voditelji radionice pripremaju radni materijal po kojemu se radionica održava i taj materijal se dostavlja polaznicima radionice.

Za potrebe radionice Konzultant osigurava dodatne privremene licence. Za održavanje radionice od Korisnika se očekuje da osiguraju dovoljan broj računala (ovisno o broju polaznika) s instaliranom 64-bitnom verzijom operacijskog sustava WINDOWS 7 ili WINDOWS 10, na kojima se instalira MIKE URBAN program.

2.1 SADRŽAJ I CILJ RADIONICE

Tijekom radionice djelatnike korisnika se nizom zadataka i vježbi uz objašnjenja provodi kroz proces matematičkog modeliranja sustava odvodnje korištenjem programa Mike Urban. Verzija programa korištena na radionici je MIKE URBAN + 2020.

Cilj radionice je sticanje osnovnog znanja iz korištenja programa, koje je osnova za kasnije samostalno korištenje isporučenog modela odvodnje Poreča, njegovo prilagođavanje i razvoj te nadogradnja.

2.2 RASPORED RADIONICE

Radionica je održan u prostorijama Odvodnje Poreč d.o.o. od 7. 10. do 9.10. 2020. godine. Raspored vježbi prikazan je u slijedećoj tablici:

<table>
<tr><th colspan="5">Obuka djelatnika o korištenju Mike Urban matematičkog modela Poreč - raspored</th></tr>
<tr><th colspan="2">Vrijeme</th><th rowspan="2">1. dan</th><th rowspan="2">2. dan</th><th rowspan="2">3. dan</th></tr>
<tr><th>od</th><th>do</th></tr>
<tr><td>9:00</td><td>9:30</td><td>Uvodna prezentacija</td><td rowspan="2">Vođena vježba "Making_a_working_model" - 1. dio</td><td>Upoznavanje s modelom Poreča - ulazni podaci</td></tr>
<tr><td>9:30</td><td>11:00</td><td>Instalacija MIKE-a</td><td>Upoznavanje s modelom Poreča - kreiranje modela</td></tr>
<tr><td>11:00</td><td>11:15</td><td>Pauza</td><td>Pauza</td><td>Pauza</td></tr>
<tr><td>11:15</td><td>11:25</td><td>Upoznavanje s programom, samostalni pregled</td><td rowspan="2">Vođena vježba "Making_a_working_model" - 2. dio</td><td>Kreiranje scenarija, rubnih uvjeta,varijacija dotoka</td></tr>
<tr><td>11:25</td><td>12:25</td><td>Vođena vježba "Getting started"</td><td>Simulacije i pregled rezultata u MU+</td></tr>
<tr><td>12:25</td><td>13:25</td><td>Pauza</td><td>Pauza</td><td>Pauza</td></tr>
<tr><td>13:25</td><td>14:25</td><td>Vođena vježba "Import nodes and links from EXCEL"</td><td>Vođena vježba "Working with TS Editor"</td><td>Pregled rezultata u MIKE View</td></tr>
<tr><td>14:25</td><td>15:00</td><td>Dnevni rezime i diskusija</td><td>Dnevni rezime i diskusija</td><td>Završna diskusija</td></tr>
</table>

Uvodna prezentacija priložena je u Prilogu ovog izvješća.

2.3 Sudionici radionice

Edukacijsku radionicu su vodili:

- Dražen Navratil, dipl.ing.građ. – Proning DHI d.o.o.
- Vedran Reiter, dipl.ing.geol. – Proning DHI d.o.o.

Sudjelovalo je 7 djelatnika Odvodnje Poreč d.o.o.:

- Zoran Ardalić – rukovoditelj sektora razvoja i investicija,
- Ivan Banić – voditelj kanalizacije
- Ugo Puniš – stručni suradnik GIS-a
- Aleksa Cvitan - stručni suradnik II
- Mateo Štifanić – pomoćnik operatera GIS-a
- Siniša Pilat - rukovoditelj sektora operative
- Karlo Gospić - vanjski suradnik

3 ZAKLJUČAK

Može se zaključiti da su sudionici zadovoljavajuće i sa razumijevanjem odradili pripremljene vježbe i ostale sadržaje.

Znanja i vještine stečene na ovoj radionici čine osnovu čijim savladavanjem su polaznici stekli znanja za samostalno korištenje programa Mike Urban te u njemu izrađenog hidrološko-hidrauličkog modela odvodnje grada Poreča te po potrebi provoditi i jednostavnije hidrološko-hidrauličke analize.

PRILOG - UVODNA PREZENTACIJA

STUDIJA POREČ - MODELIRANJE SUSTAVA ODVODNJE

Upoznavanje s osnovnim karakteristikama matematičkog modela sustava odvodnje Poreča

s obukom za njegovo korištenje unutar programa MIKE URBAN by DHI

Poreč, 7.10.-9.10.2020.

Dražen Navratil

Vedran Reiter

- MIKE by DHI lepeza programa
- MIKE URBAN
- MIKE URBAN_CS
- Osnove modeliranja u MIKE URBAN-u

1. DIO

PRONING DHI

- Osnovne informacije o modelu Poreč
- Prezentacija modela Poreč korak po korak
- Vježba za polaznike – kako dodati novi dio sustava

2. DIO

MIKE BY DHI LEPEZA PROGRAMA

MIKE URBAN+
Integrated urban water modelling in one ONE modelling platform.

WEST
Modelling and simulation of wastewater treatment plants

MIKE FLOOD
Urban, coastal and riverine flooding

WATERNET ADVISOR
Access hydraulic conditions in the city network with a web application

MIKE URBAN +

- WD - Water distribution (vodoopskrba)
- **CS - Collecting systems (sustavi odvodnje)**

MU nam pomaže modelirati sve gradske komunalne sustave, uključujući distribuciju vode, odvodnju oborinske i sanitarne vode bilo u razdjelnim ili mješovitim sustavima, kao i integriranu poplavu urbanih područja. MU nudi potpuno hidrološko i hidraulično modeliranje, uključujući i kvalitetu vode te pronos nanosa.

Najnovija verzija MU+ 2020 objedinjuje 2D modeliranje poplava temeljeno na spojenom fleksibilnom mrežnom modelu dinamički povezano s 1D modelom oborinskih voda.

MU nudi tematsko mapiranje i integriranu dinamičku vizualizaciju rezultata s podrškom za više zaslona.

Otvoreni modeli podataka - jednostavna integracija s drugim aplikacijama

With MIKE URBAN+ you have:

- GIS-based model building and management
- Powerful hydraulic simulation engines
- Integrated water quality, fire flow, and real time control simulation (water distribution)
- Integrated water quality, sediment transport, real-time control, dynamic pipe design and long-term statistics (collection systems)
- Scenario management
- Full undo and redo capability in all editors
- Thematic mapping and integrated dynamic result visualization
- Open data models - easy integration with other applications
- Worldwide support and training
- Integrates directly with online and real time control systems

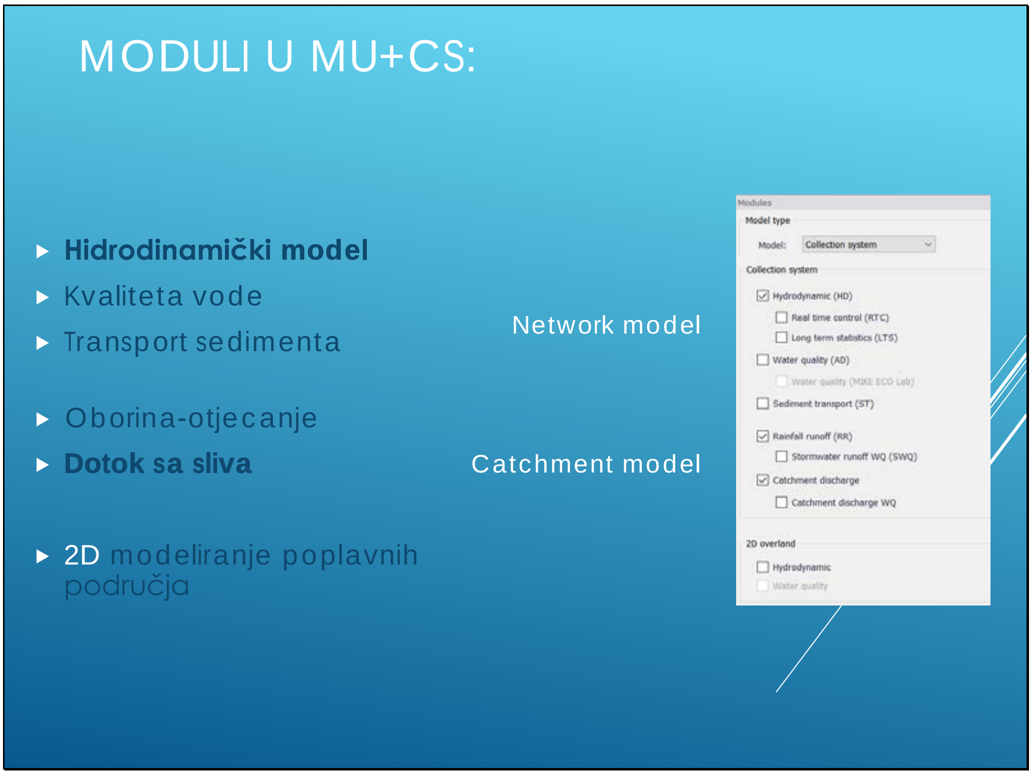
MIKE URBAN+ CS

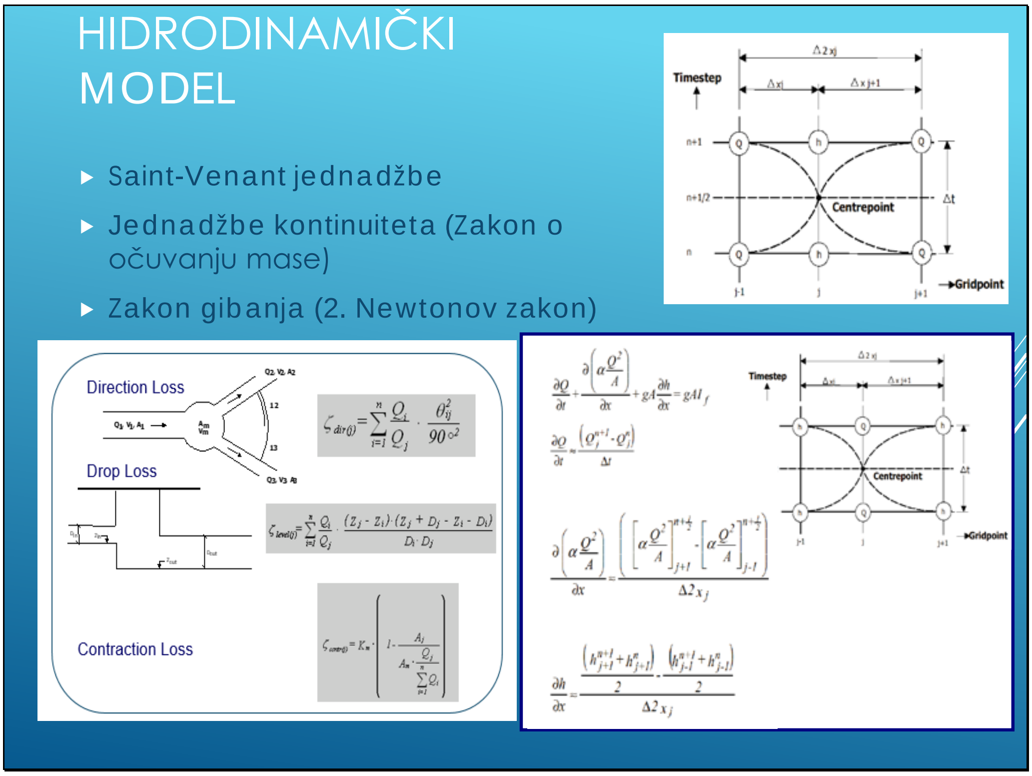
Kroz ovu radionicu upoznat ćemo vas s osnovnim konceptima modeliranja za urbanu hidrauliku kanalizacijskog sustava kao i s praktičnim stranama MU+ CS.

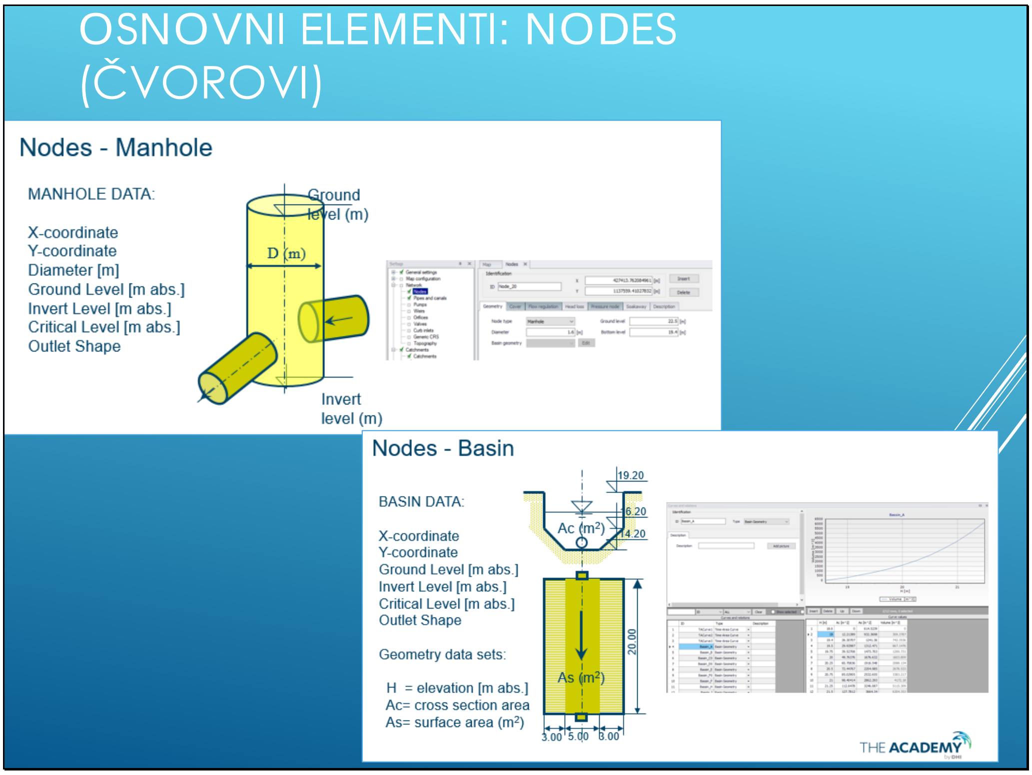
Tečaj uključuje osnove teorijskog znanja, prezentaciju primjene programa i praktične vježbe.

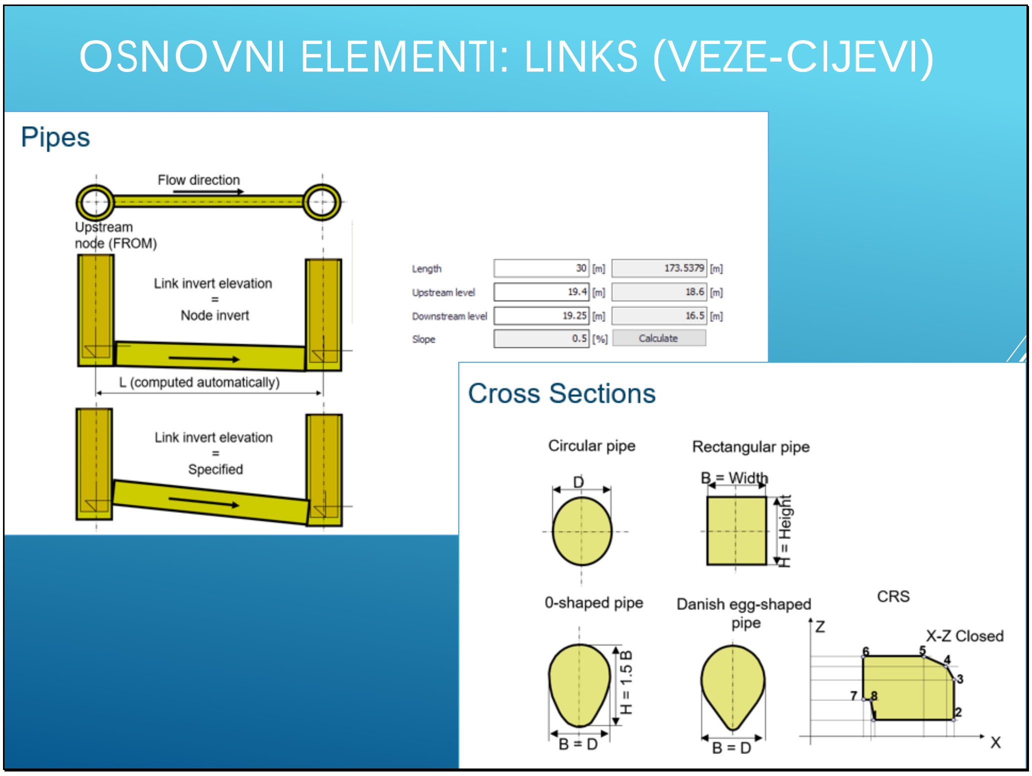
Po završetku radionice moći ćete koristiti MU+ CS za pregled i daljnje unapređenje modela uvozom GIS podataka i uređivanjem modela, pokretanje hidrauličkih simulacija, pregledom i prezentiranjem rezultata simulacija.

Osim osnova kroz koje ćemo proći tijekom radionice, MIKE URBAN+ CS, utemeljen na nasljeđu MOUSE-a i MIKE URBAN-a, nudi korisniku prilagođenu i moćnu platformu za stvarno integrirano modeliranje svih aspekata gradskih oborinskih voda i sustava odvodnje otpadnih voda, što uključuje nekoliko modela oborine, kvalitetu oborinske vode, mrežnu hidrauliku s transportom zagađenja i sofisticirani model kvalitete vode, transport sedimenata, RTC, dugoročne simulacije i najmodernije 2D modeliranje poplava urbanih područja.


MODULI U MU+CS:
Hidrodinamički model
Kvaliteta vode
Transport sedimenta
Network model
Oborina-otjecanje
Dotok sa sliva
Catchment model
2D modeliranje poplavnih područja
Modules
Model type
Model: Collection system
Collection system
Hydrodynamic (HD)
Real time control (RTC)
Long term statistics (LTS)
Water quality (AD)
Water quality (MIKE ECO Lab)
Sediment transport (ST)
Rainfall runoff (RR)
Stormwater runoff WQ (SWQ)
Catchment discharge
Catchment discharge WQ
2D overland
Hydrodynamic
Water quality

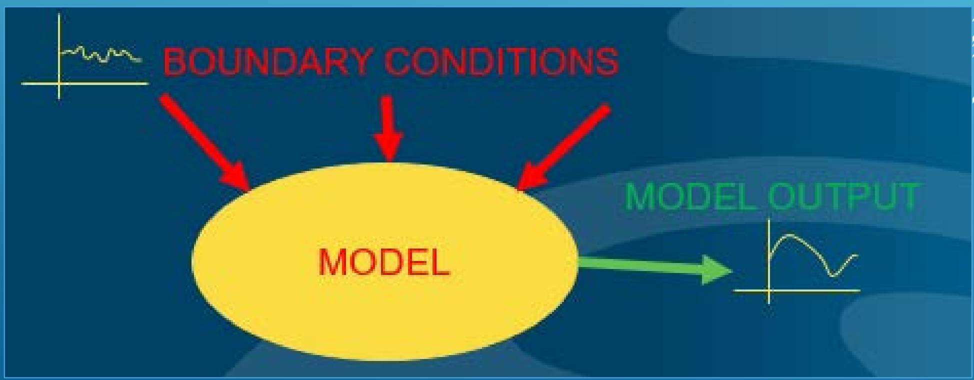

HIDRODINAMIČKI MODEL
Saint-Venant jednadžbe
Jednadžbe kontinuiteta (Zakon o očuvanju mase)
Zakon gibanja (2. Newtonov zakon)
Timestep
Centrepoint
Gridpoint
Direction Loss
Drop Loss
Contraction Loss


OSNOVNI ELEMENTI: NODES (ČVOROVI)
Nodes - Manhole
MANHOLE DATA:
X-coordinate
Y-coordinate
Diameter [m]
Ground Level [m abs.]
Invert Level [m abs.]
Critical Level [m abs.]
Outlet Shape
Ground level (m)
D (m)
Invert level (m)
Nodes - Basin
BASIN DATA:
X-coordinate
Y-coordinate
Ground Level [m abs.]
Invert Level [m abs.]
Critical Level [m abs.]
Outlet Shape
Geometry data sets:
H = elevation [m abs.]
Ac= cross section area
As= surface area (m²)
19.20
16.20
14.20
Ac (m²)
As (m²)
20.00
3.00
5.00
8.00
THE ACADEMY


OSNOVNI ELEMENTI: LINKS (VEZE-CIJEVI)
Pipes
Flow direction
Upstream node (FROM)
Link invert elevation = Node invert
L (computed automatically)
Link invert elevation = Specified
Length 30 [m] 173.5379 [m]
Upstream level 19.4 [m] 18.6 [m]
Downstream level 19.25 [m] 16.5 [m]
Slope 0.5 [%] Calculate
Cross Sections
Circular pipe
D
Rectangular pipe
B = Width
H = Height
0-shaped pipe
H = 1.5 B
B = D
Danish egg-shaped pipe
B = D
CRS
X-Z Closed
Z
X

RUBNI UVJETI (OPTEREĆENJE SUSTAVA) engl. BOUNDARY CONDITIONS

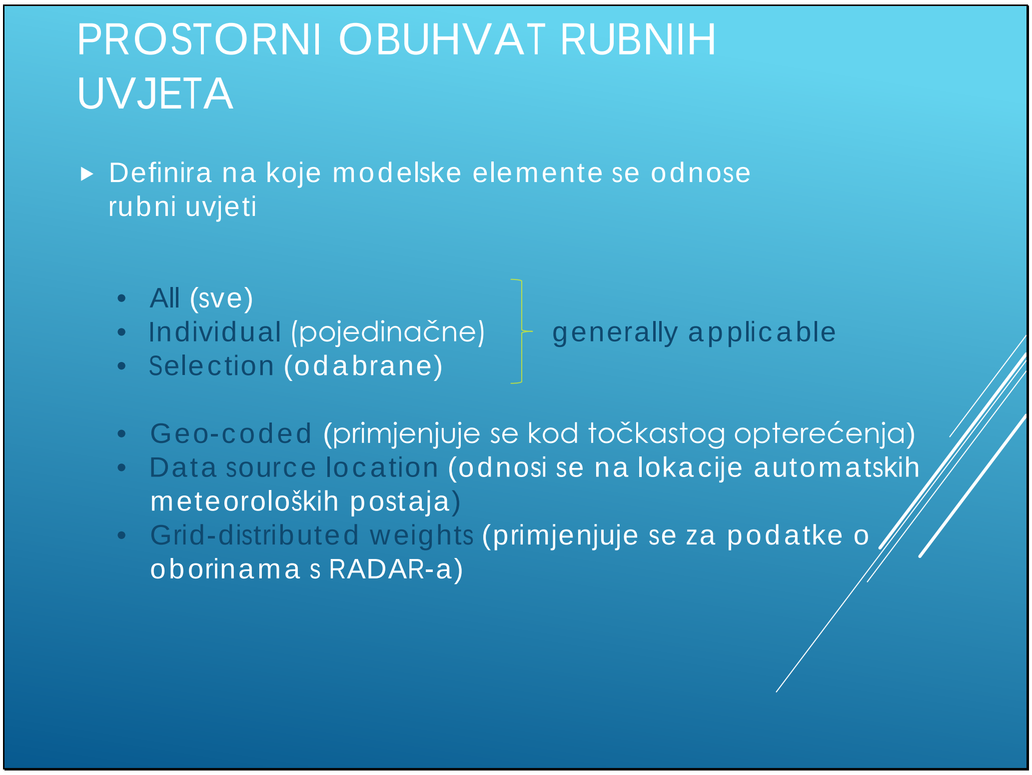
- Definiranje vanjskih utjecaja na model

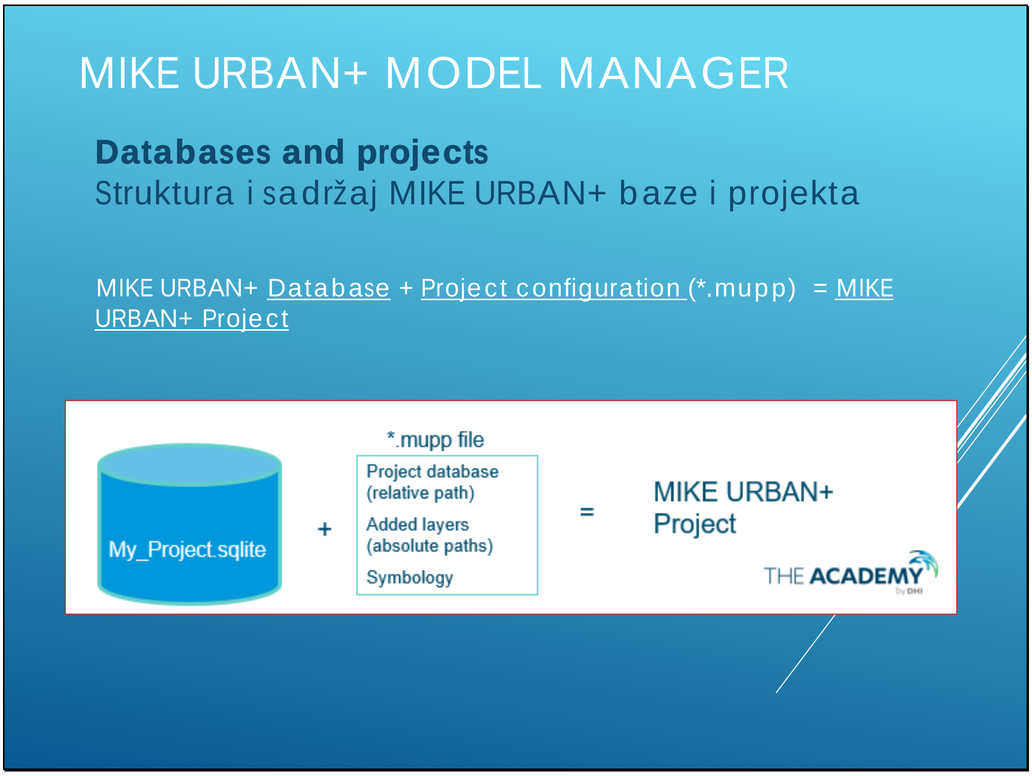


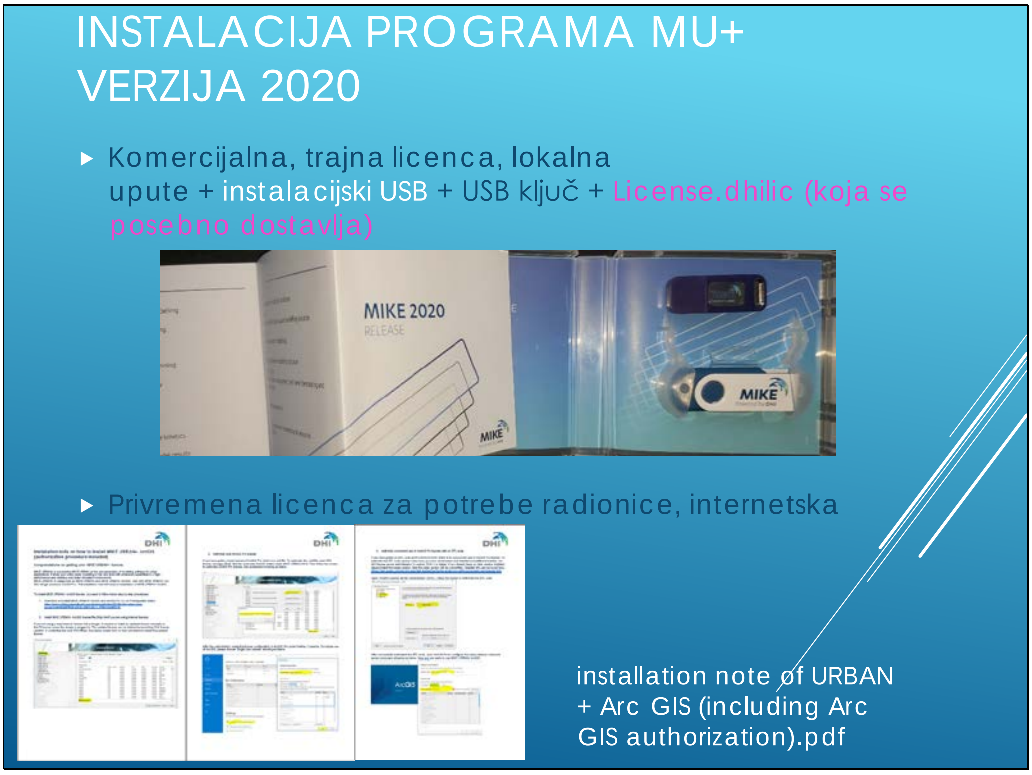
TIPOVI RUBNIH UVJETA:

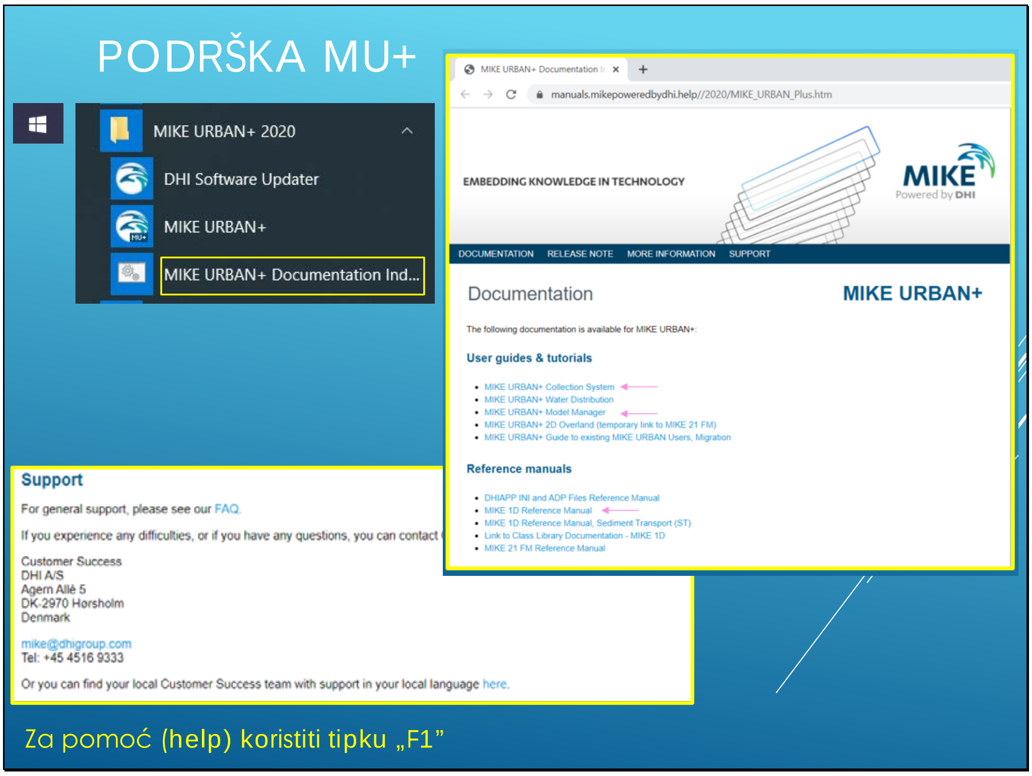
- **Catchment model (slivne površine)**
  - Rainfall
    Oborina
  - Evapotranspiration
    Evapotranspiracija
  - Air temperature
    Temperatura zraka
  - Catchment discharge (absolute, area-based, PE-based)
    Dotok sa sliva (ukupni, ovisan o površini, ovisan o broju ES)
  - Stormwater (WQ) loads
    Opterećenje zagađenjem površinske vode

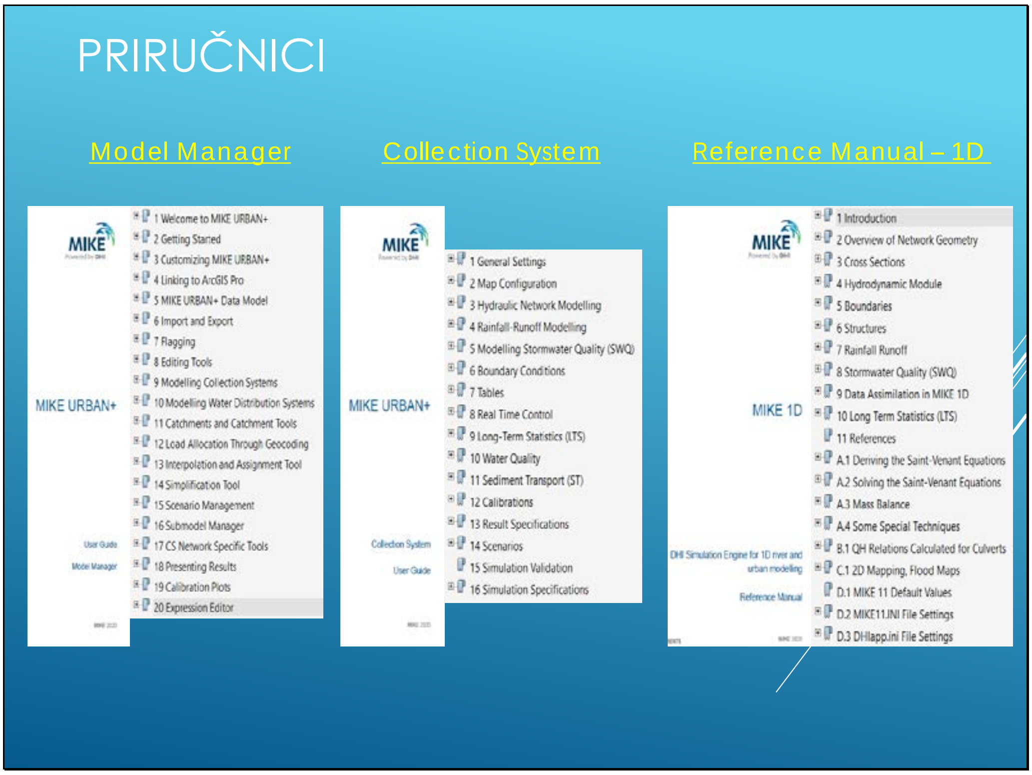
- **Network model (mreža sustava)**
  - Point loads
    Točkasto opterećenje
  - Inflows to nodes and links
    Dotok u čvor ili vezu (cijev)
  - Infiltration/exfiltration to and from nodes and links
    Infiltracija/eksfiltracija u/iz čvora/cijevi
  - Outlet water level
    Razina vode na ispustu

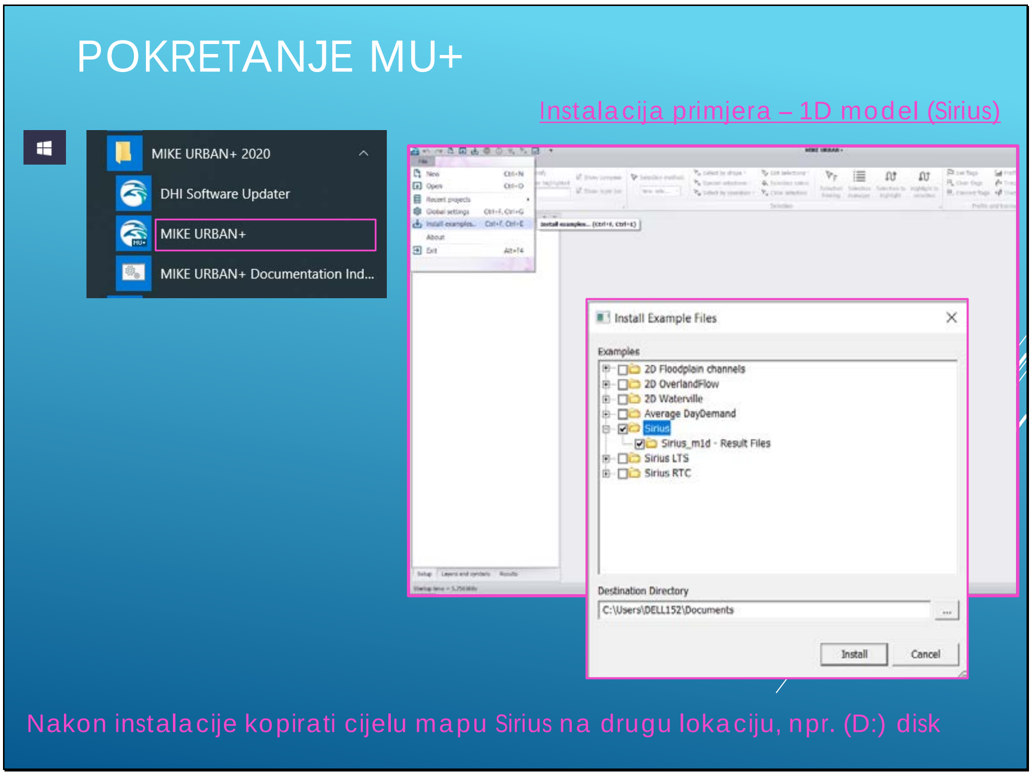

PROSTORNI OBUHVAT RUBNIH UVJETA
Definira na koje modelske elemente se odnose rubni uvjeti
All (sve)
Individual (pojedinačne)
Selection (odabrane)
generally applicable
Geo-coded (primjenjuje se kod točkastog opterećenja)
Data source location (odnosi se na lokacije automatskih meteoroloških postaja)
Grid-distributed weights (primjenjuje se za podatke o oborinama s RADAR-a)

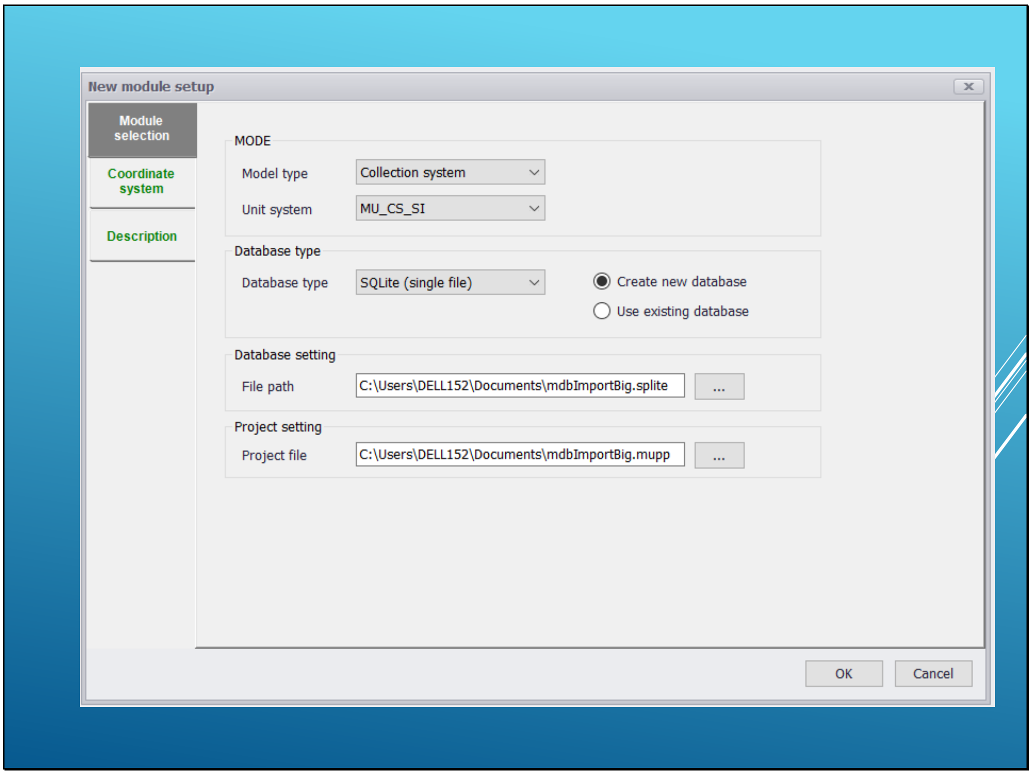

MIKE URBAN+ MODEL MANAGER
Databases and projects
Struktura i sadržaj MIKE URBAN+ baze i projekta
MIKE URBAN+ Database + Project configuration (*.mupp) = MIKE URBAN+ Project
My_Project.sqlite
+
*.mupp file
Project database (relative path)
Added layers (absolute paths)
Symbology
=
MIKE URBAN+ Project
THE ACADEMY


INSTALACIJA PROGRAMA MU+
VERZIJA 2020
Komercijalna, trajna licenca, lokalna upute + instalacijski USB + USB ključ + License.dhilic (koja se posebno dostavlja)
MIKE 2020
RELEASE
MIKE
Privremena licenca za potrebe radionice, internetska
installation note of URBAN + Arc GIS (including Arc GIS authorization).pdf


PODRŠKA MU+
MIKE URBAN+ 2020
DHI Software Updater
MIKE URBAN+
MIKE URBAN+ Documentation Ind...
MIKE URBAN+ Documentation
manuals.mikepoweredbydhi.help//2020/MIKE_URBAN_Plus.htm
EMBEDDING KNOWLEDGE IN TECHNOLOGY
MIKE
Powered by DHI
DOCUMENTATION
RELEASE NOTE
MORE INFORMATION
SUPPORT
Documentation
MIKE URBAN+
The following documentation is available for MIKE URBAN+:
User guides & tutorials
MIKE URBAN+ Collection System
MIKE URBAN+ Water Distribution
MIKE URBAN+ Model Manager
MIKE URBAN+ 2D Overland (temporary link to MIKE 21 FM)
MIKE URBAN+ Guide to existing MIKE URBAN Users, Migration
Reference manuals
DHIAPP INI and ADP Files Reference Manual
MIKE 1D Reference Manual
MIKE 1D Reference Manual, Sediment Transport (ST)
Link to Class Library Documentation - MIKE 1D
MIKE 21 FM Reference Manual
Support
For general support, please see our FAQ.
If you experience any difficulties, or if you have any questions, you can contact
Customer Success
DHI A/S
Agern Allé 5
DK-2970 Hørsholm
Denmark
mike@dhigroup.com
Tel: +45 4516 9333
Or you can find your local Customer Success team with support in your local language here.
Za pomoć (help) koristiti tipku „F1"


PRIRUČNICI
Model Manager
Collection System
Reference Manual – 1D
MIKE URBAN+
1 Welcome to MIKE URBAN+
2 Getting Started
3 Customizing MIKE URBAN+
4 Linking to ArcGIS Pro
5 MIKE URBAN+ Data Model
6 Import and Export
7 Flagging
8 Editing Tools
9 Modelling Collection Systems
10 Modelling Water Distribution Systems
11 Catchments and Catchment Tools
12 Load Allocation Through Geocoding
13 Interpolation and Assignment Tool
14 Simplification Tool
15 Scenario Management
16 Submodel Manager
17 CS Network Specific Tools
18 Presenting Results
19 Calibration Plots
20 Expression Editor
MIKE URBAN+
1 General Settings
2 Map Configuration
3 Hydraulic Network Modelling
4 Rainfall-Runoff Modelling
5 Modelling Stormwater Quality (SWQ)
6 Boundary Conditions
7 Tables
8 Real Time Control
9 Long-Term Statistics (LTS)
10 Water Quality
11 Sediment Transport (ST)
12 Calibrations
13 Result Specifications
14 Scenarios
15 Simulation Validation
16 Simulation Specifications
MIKE 1D
1 Introduction
2 Overview of Network Geometry
3 Cross Sections
4 Hydrodynamic Module
5 Boundaries
6 Structures
7 Rainfall Runoff
8 Stormwater Quality (SWQ)
9 Data Assimilation in MIKE 1D
10 Long Term Statistics (LTS)
11 References
A.1 Deriving the Saint-Venant Equations
A.2 Solving the Saint-Venant Equations
A.3 Mass Balance
A.4 Some Special Techniques
B.1 QH Relations Calculated for Culverts
C.1 2D Mapping, Flood Maps
D.1 MIKE 11 Default Values
D.2 MIKE11.INI File Settings
D.3 DHIapp.ini File Settings


POKRETANJE MU+
Instalacija primjera – 1D model (Sirius)
MIKE URBAN+ 2020
DHI Software Updater
MIKE URBAN+
MIKE URBAN+ Documentation Ind...
Install Example Files
Examples
2D Floodplain channels
2D OverlandFlow
2D Waterville
Average DayDemand
Sirius
Sirius_m1d - Result Files
Sirius LTS
Sirius RTC
Destination Directory
C:\Users\DELL152\Documents
Install
Cancel
Nakon instalacije kopirati cijelu mapu Sirius na drugu lokaciju, npr. (D:) disk



SLIJEDE VJEŽBE U MIKE+ CS

- Getting started
- Import model data from Excel
- Editing model data
- Time series editor
- Export to ArcGIS

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 17 dio 2/4

EDUKACIJA DJELATNIKA: MODELIRANJE MORA

Studeni 2021

Zajednica izvršitelja

Naručitelj

Krajnji korisnik

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 17 dio 2/4

EDUKACIJA DJELATNIKA: MODELIRANJE MORA

13. studeni 2021

mr.sc. Božidar Deduš, dipl. ing.
Ovlaštenik Zajednice izvršitelja
Proning DHI d.o.o.

10. studeni 2021

prof.dr.sc. Damir Brdjanovic, dipl.ing.
Voditelj stručnog tima
IHE Delft

REPORT

HRVATSKE VODE

Sea Water Quality Modelling Istria

Education Report

8 December 2021 - version 1.0

International Marine & Dredging Consultants

Colophon

International Marine & Dredging Consultants

Address: Van Immerseelstraat 66, 2018 Antwerp, Belgium

☎: + 32 3 270 92 95

: + 32 3 235 67 11

Email: info@imdc.be

Website: www.imdc.be

Document Identification

Title	Education Report
Project	Sea Water Quality Modelling Istria
Client	HRVATSKE VODE -
Tender	OP 2015/227
Document ref	I/RA/12142/20.031/ABR/,
Document name	K:\PROJECTS\12\12142_P009187 - Sea Water Quality Modelling Istria\10-Rap\DO-1\RA20031_Education report\RA20031_Water_quality_modelling_Education_report_v0.2.docx

Revision

Version	Date	Description	Author	Checked	Approved
1.0	08/12/2021	Final version	ABR	VBA	VBA

Approval

Author	ABR	
Checked	VBA	
Approved	VBA	

Contact within IMDC

Name	**Bart Verheyen**
Phone number	+32 3 270 92 95
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Distribution List

0	Hard copy	
1	PDF	Damir Brdjanovic (IHE-UNESCO)

Table of Contents

Annexes

1. INTRODUCTION

1.1 THE ASSIGNMENT

Large investments in the public sector are ongoing along part of the Istrian coast including the renewal and extension of the existing drainage system and the construction of new waste water treatment plants for the purpose of protecting the city of Poreč and surroundings.

IMDC was requested to perform sea water quality modelling of the dispersion of sewage effluent (faecal bacteria) along the Istrian coast, Croatia. Using numerical models, the bathing water quality has been investigated in the present situation as well as after the installation of the treatment plants. The study assesses the risk of E-Coli (EC) and Intestinal Enterococci (IE) pollution (as indicator for the bathing water quality) at the beaches and the added value of treatment plants to reduce this risk. The study is part of the overall assignment "Study evaluation and monitoring of the effectiveness of the implementation of the construction project of sewerage network and analysis of the effectiveness of waste water treatment plant operation Poreč" issued by Hrvatske Vode (Croatian Waters) with the tender OP 2015/227. The work was assigned to the consortium including IMDC and represented by PRONING DHI as Lead Member with the contract on 19/07/2018, Class: 325-01/15-10/148, Reg: 374-1- 3-18-35. A consortium agreement was concluded on 13/05/2016 and extended with annex I on 13/11/2018.

IMDC will contribute to the following requested deliverables:

- Report on hydrodynamic model setup (IMDC, 2019a);
- Report on hydrodynamic model calibration and modelling of present situation (IMDC, 2019b);
- Report on sea water quality model calibration and modelling of present situation (IMDC, 2021a);
- Report on the impact of WWTP on bathing water quality: scenario modelling (IMDC, 2021b);
- Report on the impact of WWTP on bathing water quality: model validation;
- Report on model handover and training (this report).

1.2 SCOPE OF THE REPORT

This report describes the training and model handover that were organised in Poreč, Croatia from October 20 to October 22 2021.

1.3 READING GUIDANCE

In this report, the training that was given in Poreč is presented. Thereto, the course objectives, course program and a short description of the content of the course are presented in chapter 2. In chapter 3 , some conclusions are given on whether the objectives of the course were met. The slides of the course are included in Annex A. The review of the course provided by the participants in given in Annex B.

2. OVERVIEW OF THE COURSE AND HANDOVER

2.1 INTRODUCTION

In this chapter, the objectives and program of the course are given first, followed by a short description of the contents of the course.

2.2 OBJECTIVE OF THE COURSE

Objectives of the training are:

- To gain insight in the use and applications of numerical models with a focus on hydrodynamics and water quality and the typical steps in performing a hydrodynamic modelling study
- To learn how to compile and install TELEMAC on a computer
- To get introduced to the structure and use of TELEMAC
- To gain knowledge on the numerical methods in TELEMAC
- To learn how to pre-process a simulation, manipulate meshes, bathymetry, roughness, boundary conditions, and apply other (numerical) settings
- To learn how to run TELEMAC and post-process the results using BlueKenue.
- To learn about error messages and problem solving
- To gain insight in the TELEMAC Istria model (hydrodynamics and plume dispersion)
- To run scenarios with the TELEMAC Istria model by making changes to the mesh, model bathymetry and boundary conditions

2.3 COURSE PROGRAM

Day 1		
07h30-09h00	*Introduction to hydrodynamic processes*	Lecture
09h15-10h45	*Introduction to TELEMAC*	Lecture
10h45-11h45	lunch	
11h45-13h15	*TELEMAC installation on participants laptop*	Hand-on
13h30-15h00	*Introduction to preprocessing and mesh making with BlueKenue (1)*	Hands-on
Day 2		
07h30-09h00	*Project cycle in hydrodynamic modelling*	Lecture

Day 1		
09h15-10h45	*Introduction to setting-up a TELEMAC model and postprocessing using BlueKenue*	Hands-on
10h45-11h45	lunch	
11h45-13h15	*Running a TELEMAC model and postprocessing using BlueKenue*	Exercise
13h30-15h00	*Numerical methods for hydrodynamic modelling*	Lecture
Day 3		
07h30-09h00	*Problem solving while running TELEMAC code*	Hands-on
09h15-10h45	*Problem solving while running TELEMAC code*	Exercise
10h45-11h45	lunch	
11h45-13h15	*Overview of the Istria models (1)*	Hands-on
13h30-15h00	*Overview of the Istria models (2)*	Hands-on

2.4 ACTIVITY REPORT

2.4.1 Day 1

On the first day, the course started with the two theoretical lectures. The first lecture gave an introduction to the physics of hydrodynamic processes and water quality, which form the basis of hydrodynamic modelling. An understanding of these processes is important in order to be able to interpret the results of any hydrodynamic model The focus hereby was on understanding of the physical processes, rather than on mathematical equations. Physical processes that were introduced included tidal flow, wind driven currents, stratified flows, Coriolis force and turbulence. Also some particular attention was given to various modelling approaches (such as fully 3D, quasi3D hydrostatic or depth-averaged 2DH modelling).

The second lecture introduced the TELEMAC suite, first discussion the various modules inside TELEMAC. This was followed by an overview on some characteristics of the hydrodynamic modules of TELEMAC-2D and TELEMAC-3D (such as the way). Finally the different input files needed in TELEMAC were discussed.

During the third lecture, all necessary software was installed on the computers of the participants, including the BlueKenue pre and postprocesser, the mingw compiler suite, Python Anaconda, MPI for parallel computations and TELEMAC (cookiecutter shark version based on v7p2, which is the version of TELEMAC used for the Istria models). Various tests were performed to check that the installation worked well.

In the final lecture a start was made with the teaching of the BlueKenue software, discussing how to make unstructured meshes in BlueKenue. This was organised as a hands-on session

2.4.2 Day 2

At the start of the day 2, the fourth lecture of day 1 was continued, as it appeared a bit more time was needed for this. Hence the part on preparing a model using BlueKenue was continued, focussing on determining boundary conditions for the simulations and the different ways to prescribe the bathymetry of the model.

After finishing the lecture on preparing mesh input, a theoretical lecture was given, explaining the different steps that need to be taken in performing a modelling study, starting from an analysis of the studied system, and determining the objective of the model. Other topics included data analysis, generating the mesh, determining the model settings and boundary conditions, as well as the calibration and validation of the model. This was illustrated by showing some examples of different models applied in practice.

After this lecture, the working on TELEMAC models was continued by making a new TELEMAC-2D model of a simple geometry (a river with a small harbour) from scratch in a hands on way. Then, the necessary steering file was made, and the model was run on the laptops of the participants. This was done both in serial as well as in parallel mode to show the potential of parallel computing in decreasing the calculation time. Using the result files of the model, the BlueKenue training was continued focussing on postprocessing the results.

In the final lecture of the day, numerical methods and parallelisation were discussed. Hereto an overview of characteristics of numerical schemes was given (such as numerical diffusion and dispersion, mass conservation and stability). The focus hereby was not on mathematics, but more on understanding of how results numerical calculations are influenced by different numerical effects . This was illustrated by an hands-on demonstration, in which different advection schemes were run in a simple test case. The results of these simulations were compared such that the impact of the choice of the advection scheme on the results could be studied (visualizing this in BlueKenue). Also the impact on the calculation time was discussed on this. The lecture ended with a short introduction on how parallel calculations work in TELEMAC.

2.4.3 Day 3

At day 3, a start was given with a short recapitulation of what was learned so far. In this recapitulation, a small TELEMAC-2D model was made from scratch. The model was run, and then the results were inspected in BlueKenue, critically assessing that the results indeed made sense.

The rest of the morning session focused on problem solving in TELEMAC. Hereby, first a lecture as given, showing the different things that can go wrong and how to solve these issues. This was followed by an exercise, in which six different models were given to the participants, each of which had one or more problems, such that they did not run properly. In a joint exercise, all the issues were solved, and the results of each of the small simulations was examined, to verify that indeed they worked correctly.

In the afternoon session, the model handover was performed. Here, the model settings, mesh, calibration and verification were presented (following the steps taught in the lecture on the hydrodynamic modelling cycle). During these steps, the different model files (e.g. mesh/ bathymetry and steering files) were opened by the participants, in order to inspect the model and to get a feeling how the model works.

3. CONCLUSION

In the training, the participants learned how to use TELEMAC, ranging from setting up a model, to running, solving eventual problems during this stage to postprocessing the results. A theoretical background needed for this (consisting of some basics on hydrodynamic modelling, physics of hydrodynamic processes and basic information on numerical methods) was also taught during the course. The models that were developed for this project (a model of the Adriatic Sea and a medium scale model, predicting the dispersion of faecal bacteria) were also introduced in detail during the course. With these information, the objectives of the course were met. The review by the participants (Annex B) shows that the course was appreciated by them.

4. REFERENCES

IMDC (2019a). Sea water quality modelling Istria. Hydrodynamic model setup. I/RA/12142/18.174/VBA/.

IMDC (2019b). Sea water quality modelling Istria. Hydrodynamic model calibration. I/RA/12142/19.072/RKU/.

IMDC (2021a). Sea water quality modeling Istria. Water quality model calibration and present situation. I/RA/12142/21.147/VBA/.

IMDC (2021b). Sea water quality modeling Istria. Impact of WWTP on bathing water quality: scenario modelling. I/RA/12142/21.226/VBA/.

Annex A Course materiel

Lecture 1.1: Hydrodynamics in the marine & coastal environment

Objective of the course (1)

- To gain insight in the use and applications of numerical models with a focus on hydrodynamics and water quality and the typical steps in performing a hydrodynamic modelling study
- To learn how to compile and install TELEMAC on a computer
- To get introduced to the structure and use of TELEMAC
- To gain knowledge on the numerical methods in TELEMAC
- To learn how to pre-process a simulation, manipulate meshes, bathymetry, roughness, boundary conditions, and apply other (numerical) settings
- To learn how to run TELEMAC and post-process the results using BlueKenue.
- To learn about error messages and problem solving

Objectives of the course (2)

- To gain insight in the TELEMAC Istria model (hydrodynamics and plume dispersion)
- To run scenarios with the TELEMAC Istria model by making changes to the mesh, model bathymetry and boundary conditions

Program

- Day 1 – morning:
  - *Introduction to hydrodynamics*
  - *Introduction to TELEMAC*
  - *TELEMAC installation on participants laptop (hands- on)*
- Day 1 – afternoon:
  - *Preprocessing and mesh making with BlueKenue (hands-on)*

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Program

- Day 2 – morning:
  - *Project cycle in hydrodynamic modelling*
  - *Running a TELEMAC model and postprocessing using BlueKenue (hands-on)*
  - *Setting up, running and postprocessing a TELEMAC model (exercise)*
- Day 2 – afternoon:
  - *Theory numerical methods and for hydrodynamic modelling*

Program

- Day 3 – morning:
  - *Problem solving while running TELEMAC code (hands-on)*
  - *Problem solving while running TELEMAC code (exercise)*
  - *Overview of the Istria Model (hands-on)*
- Day 3 – afternoon:
  - *Implementing scenarios in the Istria Model (hands-on)*

Hydrodynamics in the marine & coastal environment

- Part 1 – General Aspects
- Part 2 – Navier-Stokes equations
- Part 3 – Momentum equations in 1D, 2D, 3D
- Part 4 – Transport of tracers

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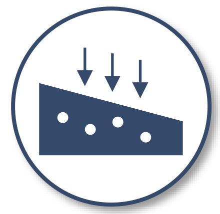
Part 1
General Aspects

Types of hydrodynamic loads on marine infrastructure

Tidal currents



Density currents

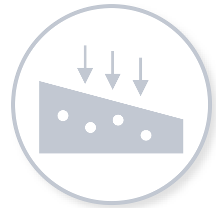
Global circulation currents

Wind-driven currents

Waves

Types of hydrodynamic loads on marine infrastructure

Tidal currents



Density currents

Global circulation currents

Wind-driven currents

Waves

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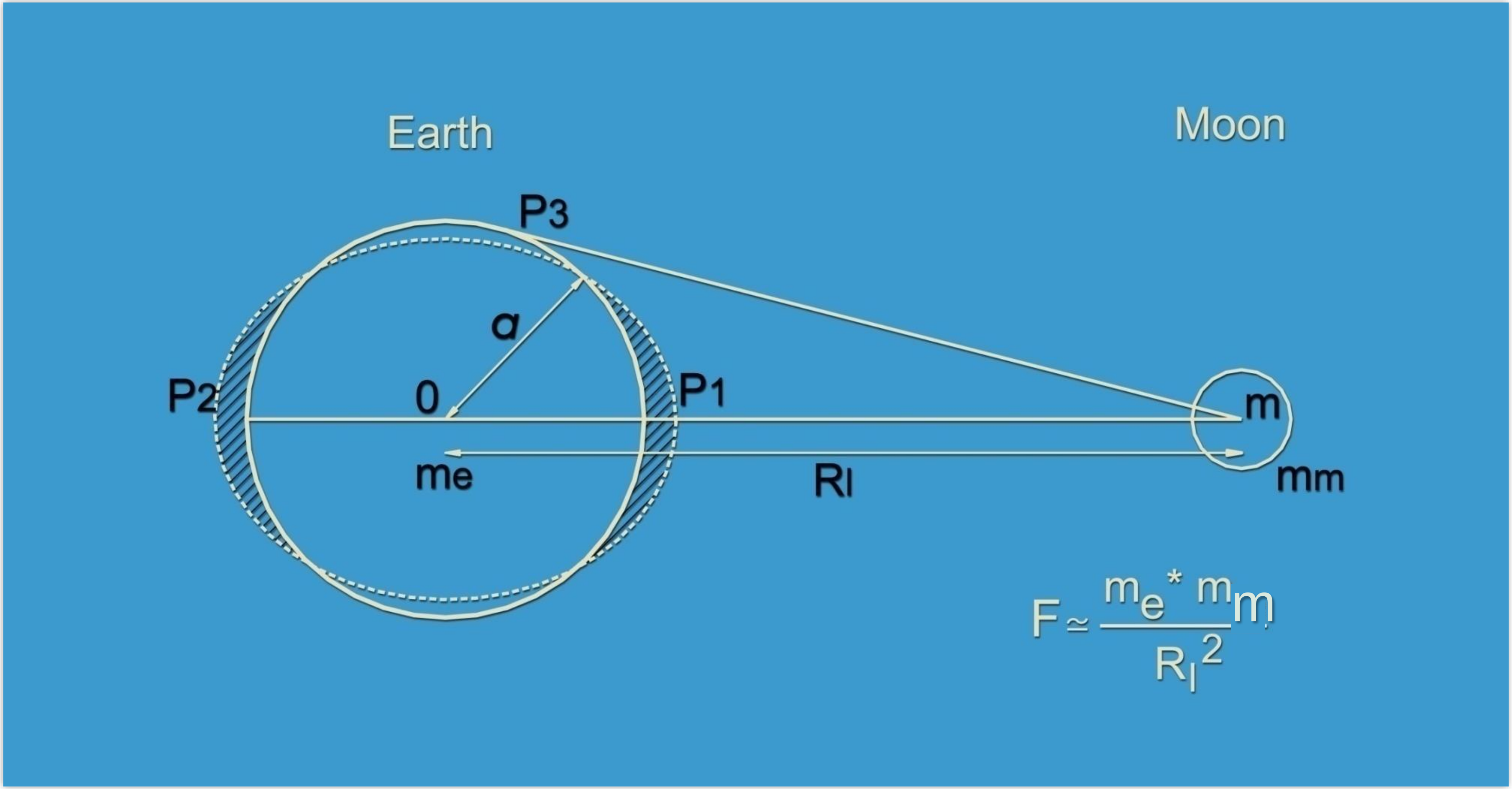
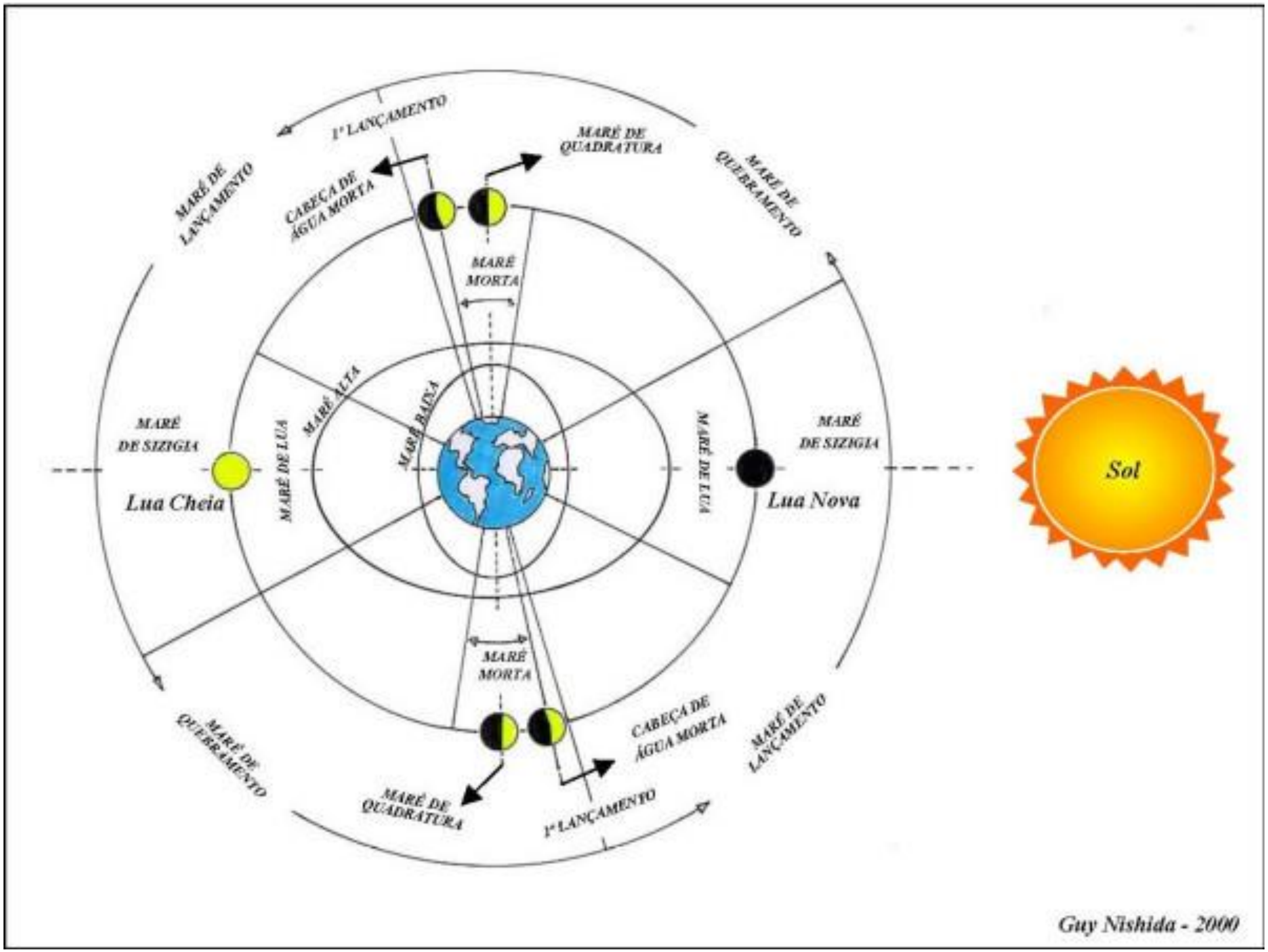
Tides

- Idealized tides:
  - Tides on a spherical earth
  - No influence of land masses
  - Only determined by motion of earth, moon and sun
- Real tides:
  - Tides in our oceans
  - Influenced by land masses, shapes of oceans and seas and bathymetry

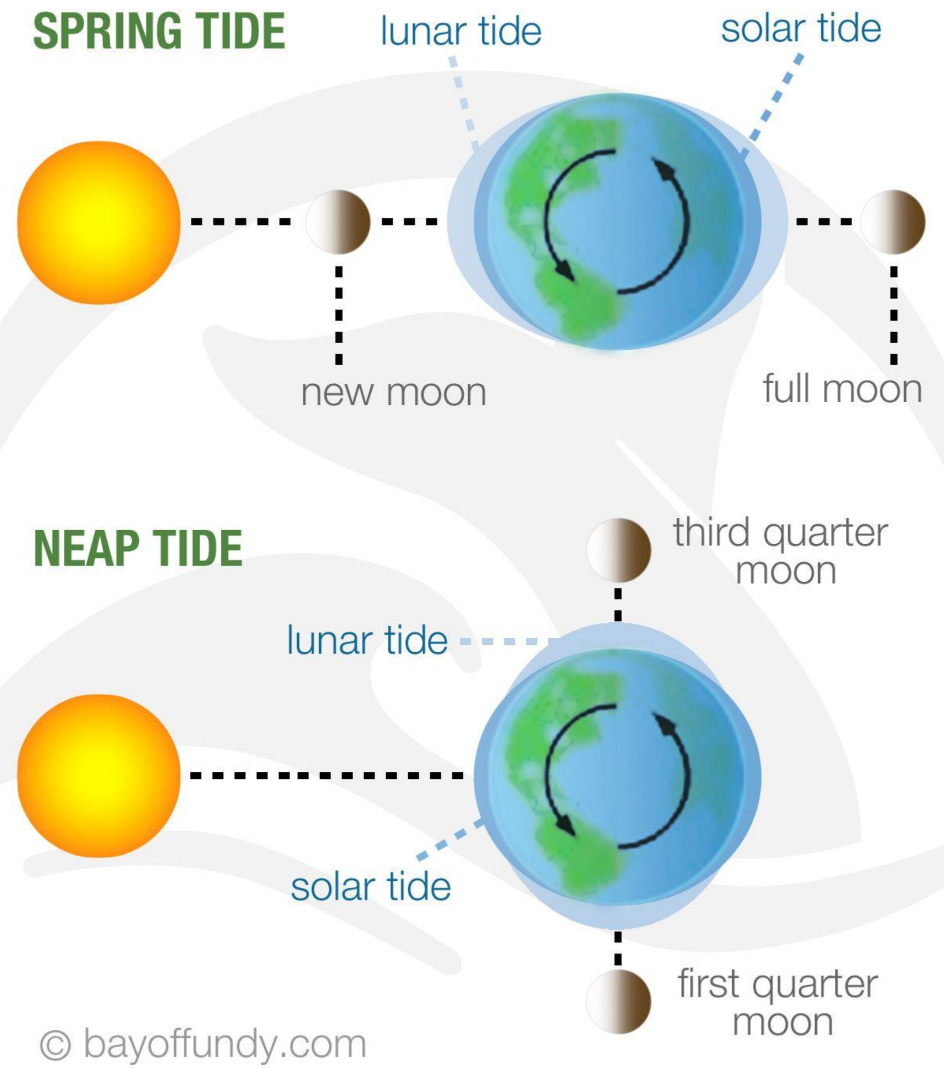
Origin of tides – high and low tide



Origin of the lunar period (12h25 minutes)



Origin of tides – neap and spring tide



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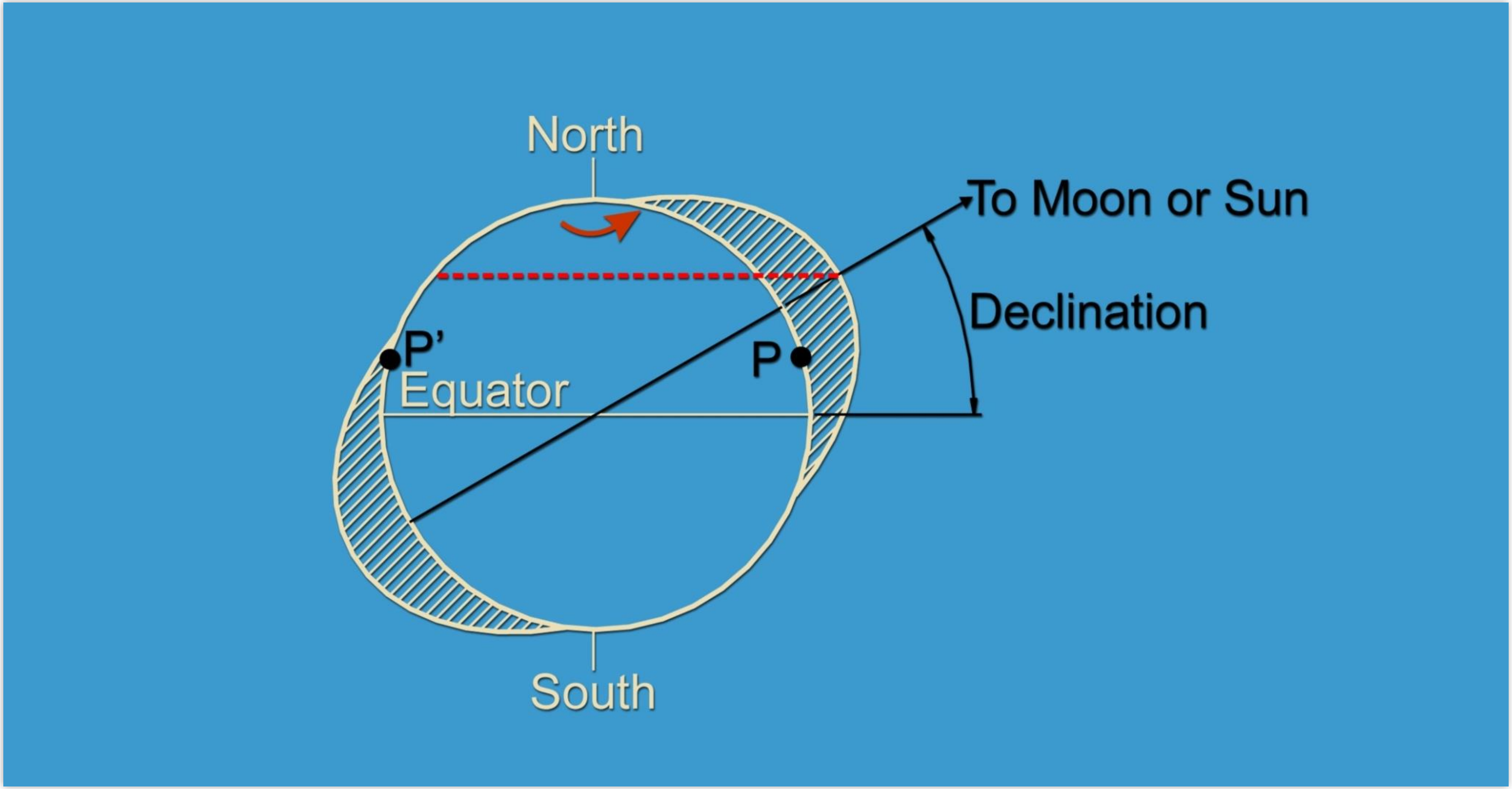
Origin of tides – daily inequality

Earth



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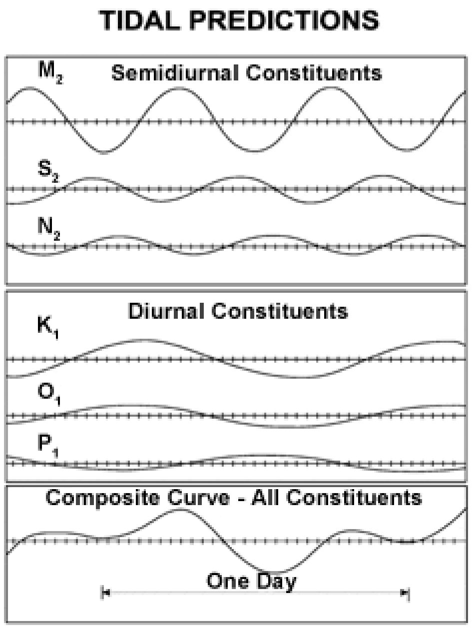
Tidal components

Species	Darwin Symbol	Period (hr)
Principal lunar semidiurnal	M_2	12.4206
Principal solar semidiurnal	S_2	12
Larger lunar elliptic semidiurnal	N_2	12.6583
Lunar diurnal	K_1	23.9345
Lunar diurnal	O_1	25.8193



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Real tides

- Tides are influenced by shapes of the basins:
  - Resonance can occur
  - Tide influenced by non-linearities (higher order tides e.g. M4)
  - Tide influenced by bottom friction (higher order terms e.g. M6)

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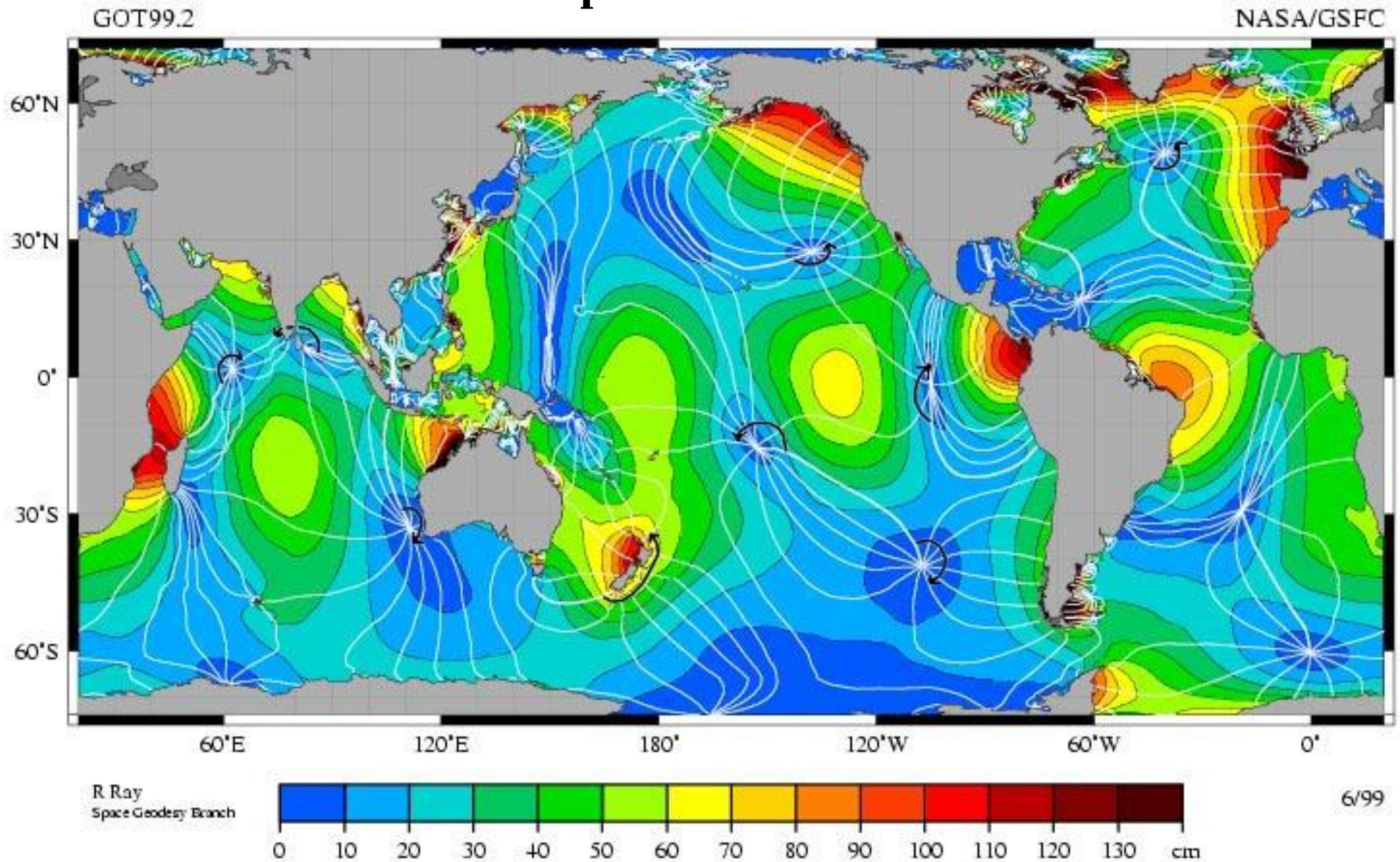
Origin of tides – Lunar tide

Amplitude lunar tide



Tidal range

Earth

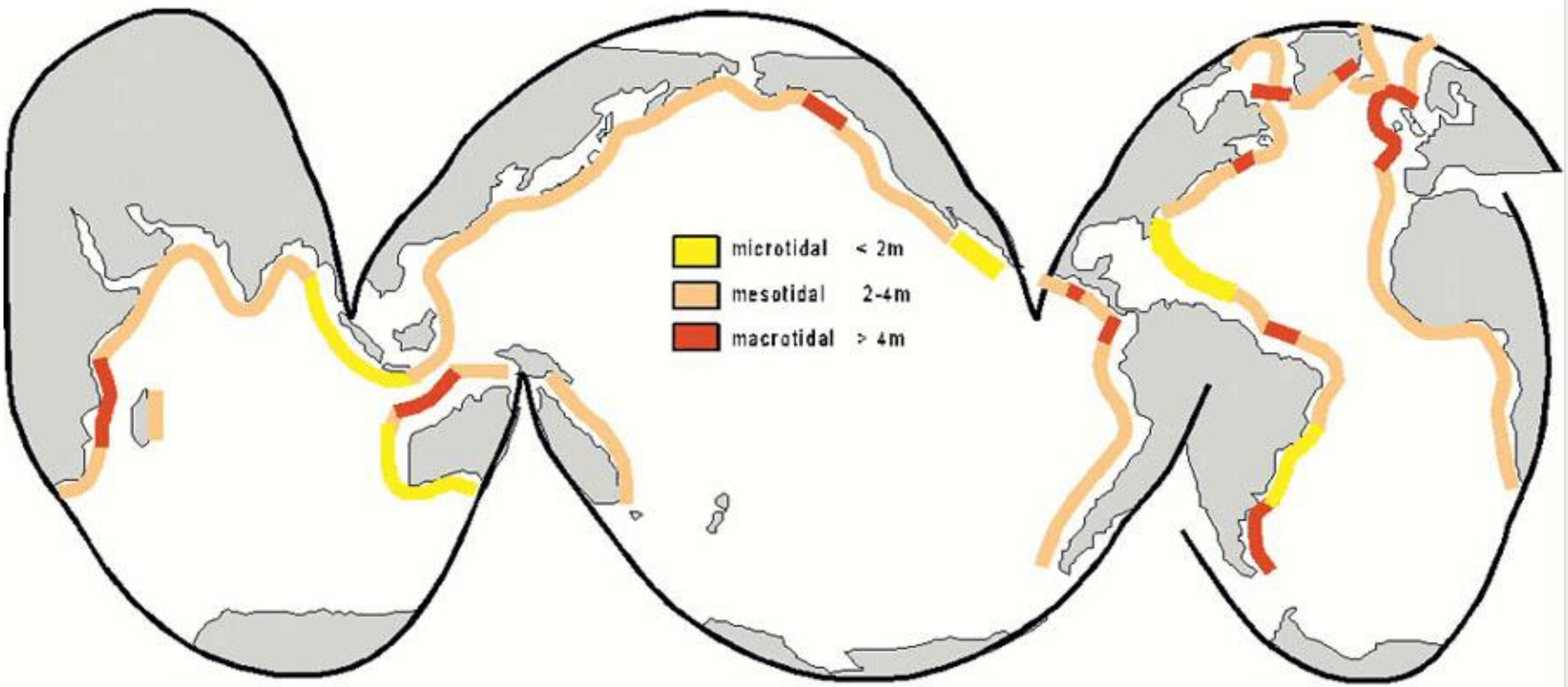


Figure Worldwide distribution of coastal tidal ranges.

http://geology.uprm.edu/Morelock/tide.htm

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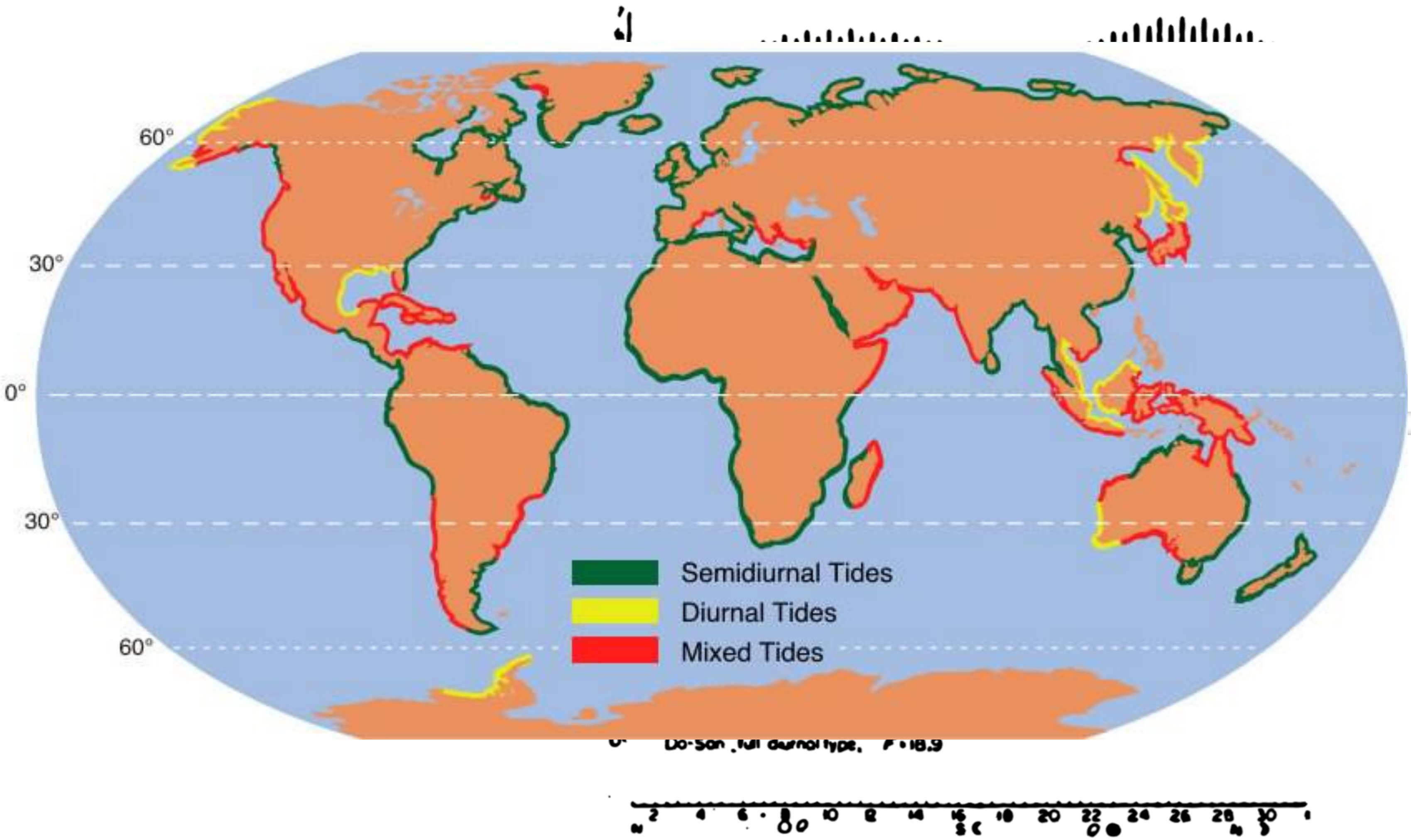
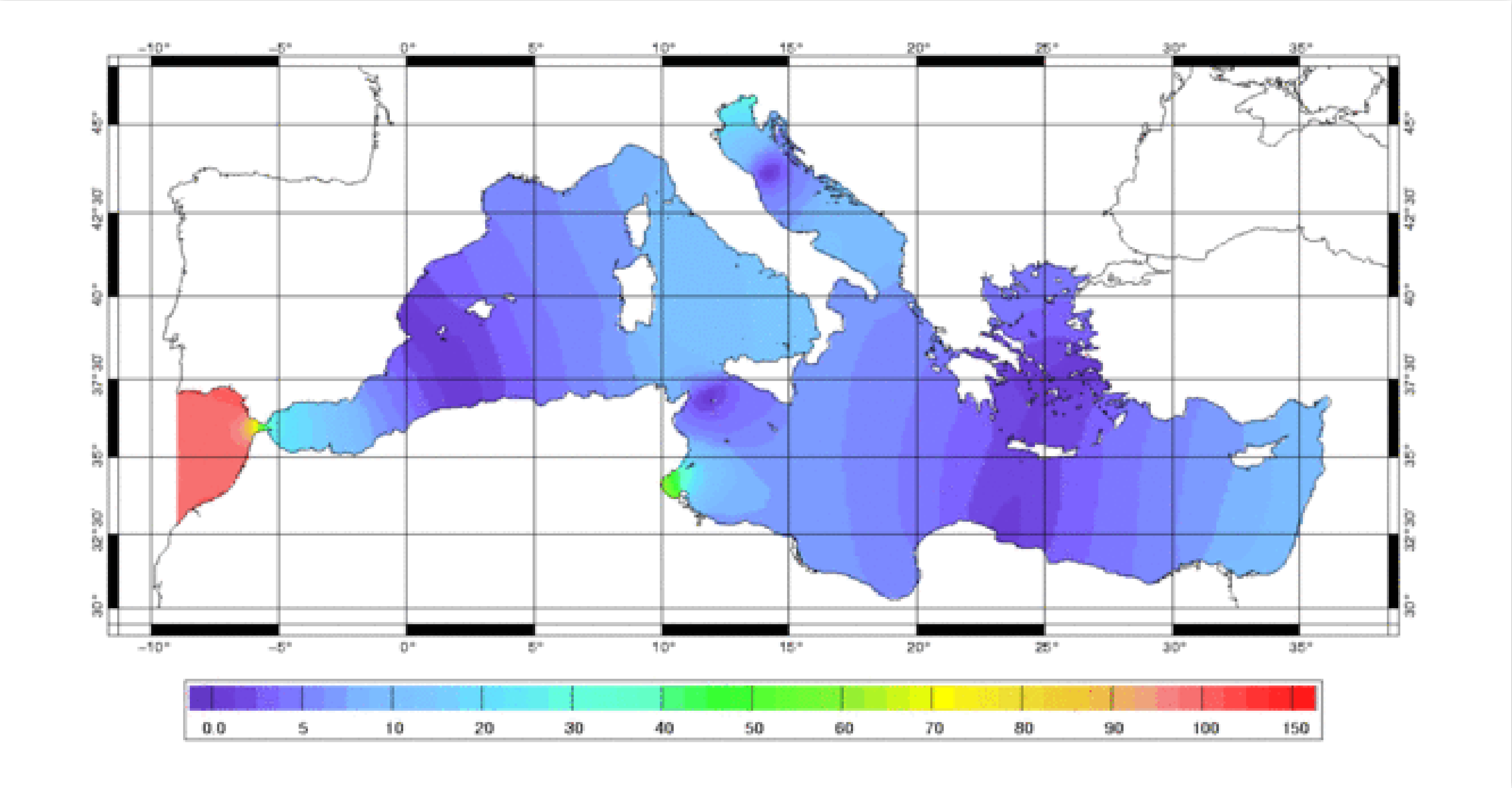
Type of tides



Tidal amplitude Mediterranean

Earth



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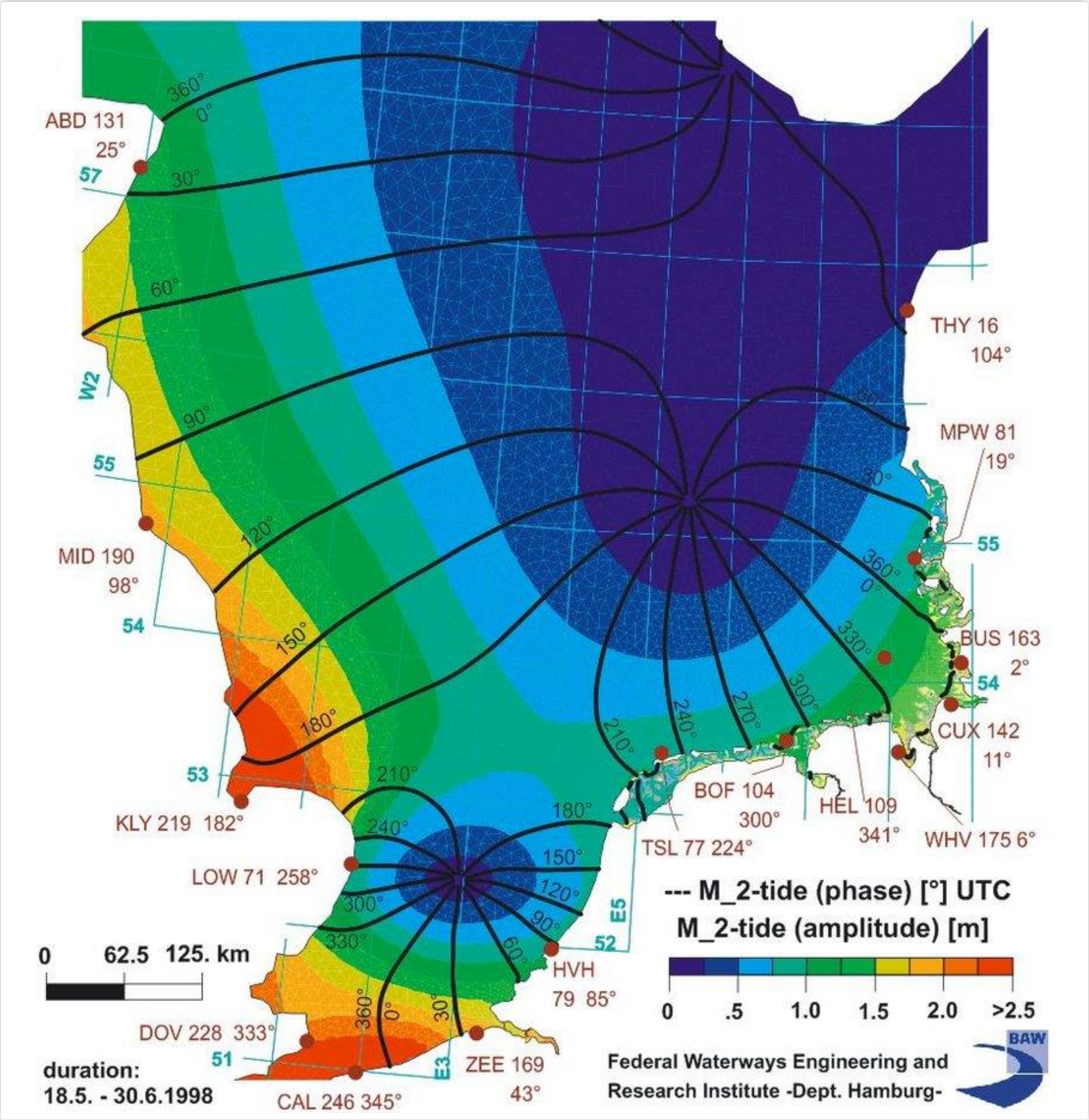
Tidal amplitude North Sea



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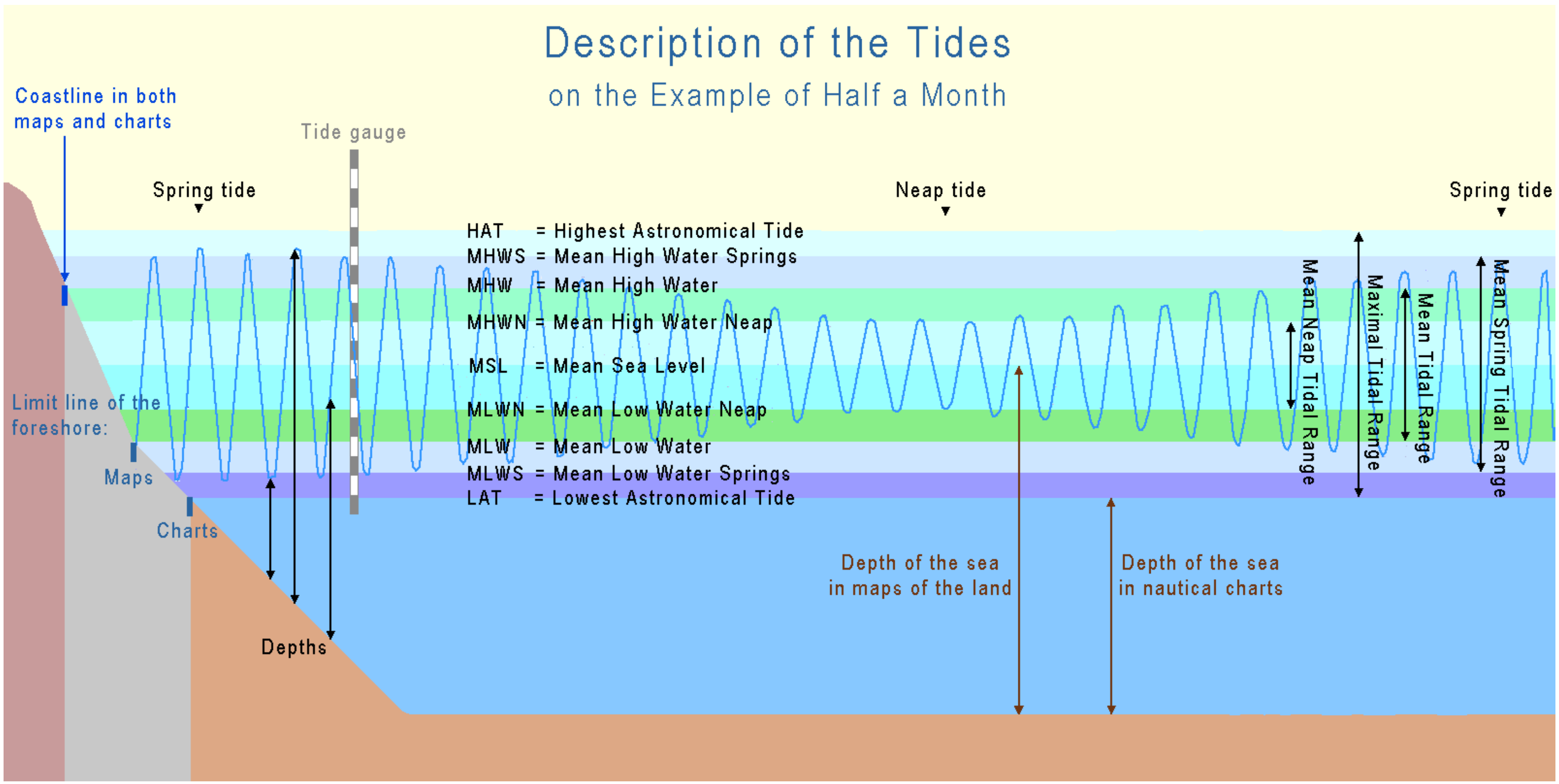
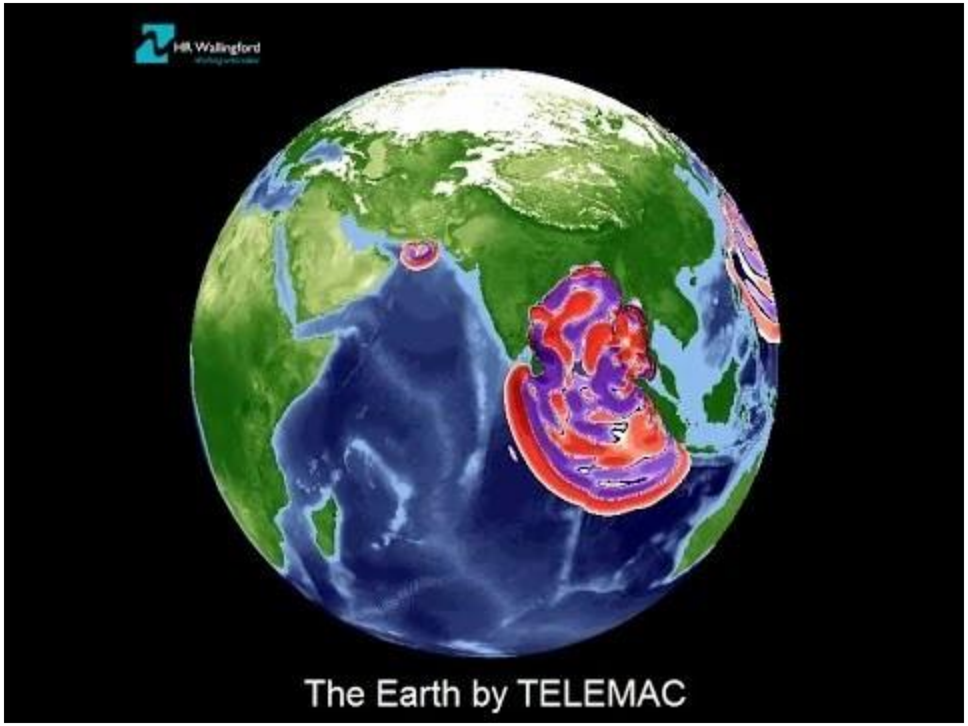
Different water levels



Tsunami's

Earth



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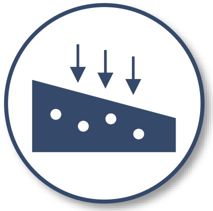
Types of hydrodynamic loads on marine infrastructure

Tidal currents



Density currents

Global circulation currents

Wind-driven currents

Waves

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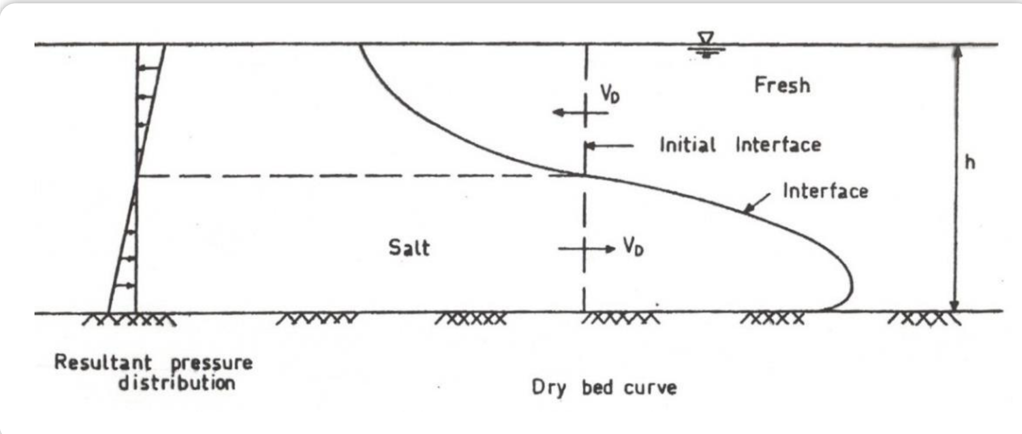
Density currents

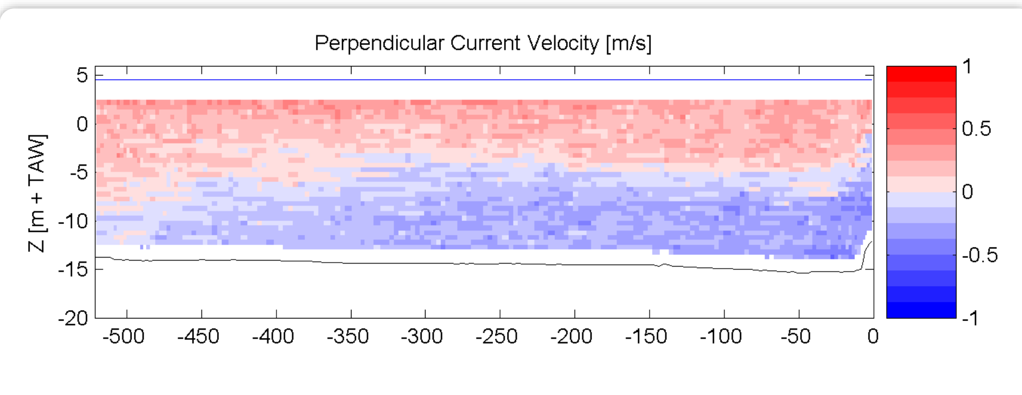
- Non-uniform water density through:
  - Temperature gradients
  - Salinity gradienst
  - Dispersed particles (sediment)
- Extra force due to horizontal density gradients (baroclinic pressure)
- Damping of turbulence (due to vertical density gradients)

Salinity – Density Currents

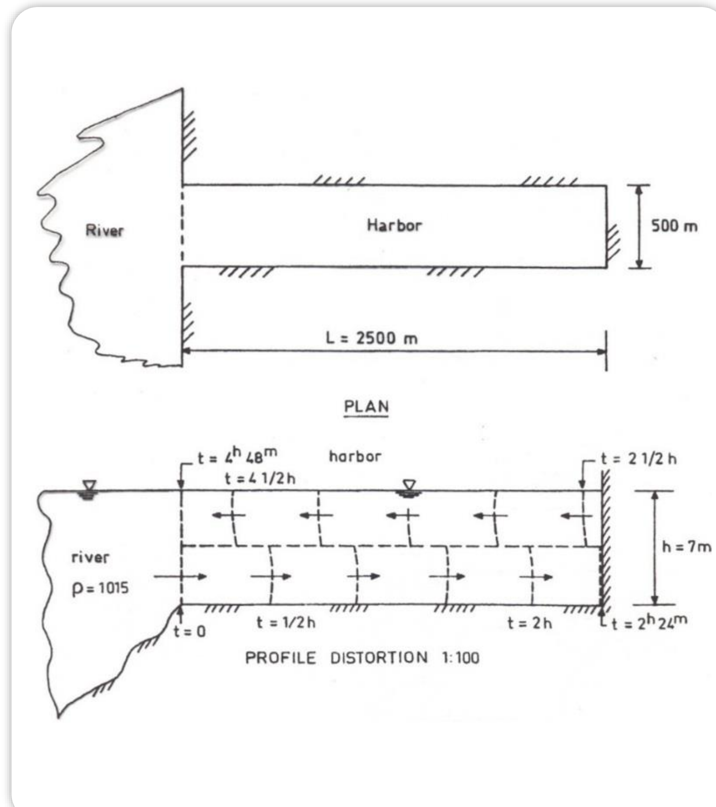
Density current forces and motion



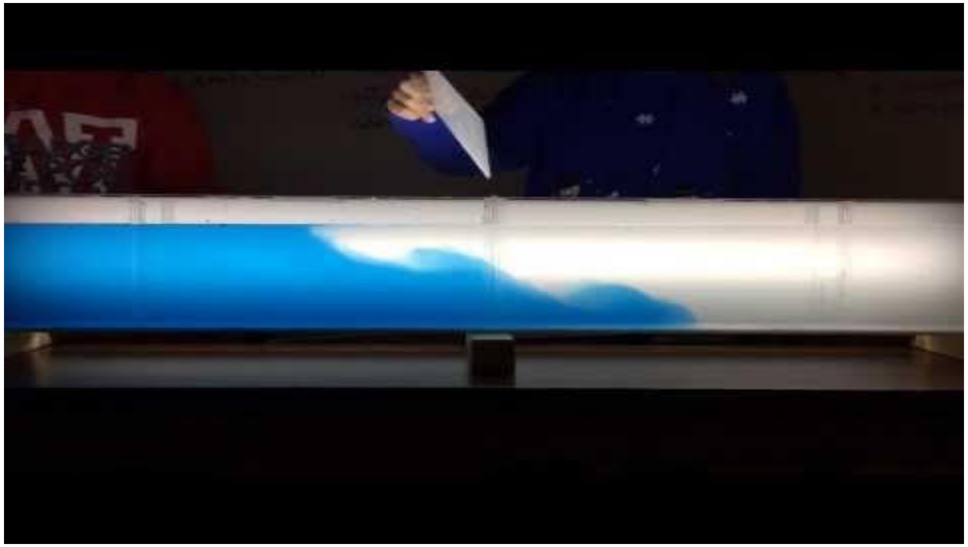
Perpendicular current velocity (m/s)



Progress of density current in harbour



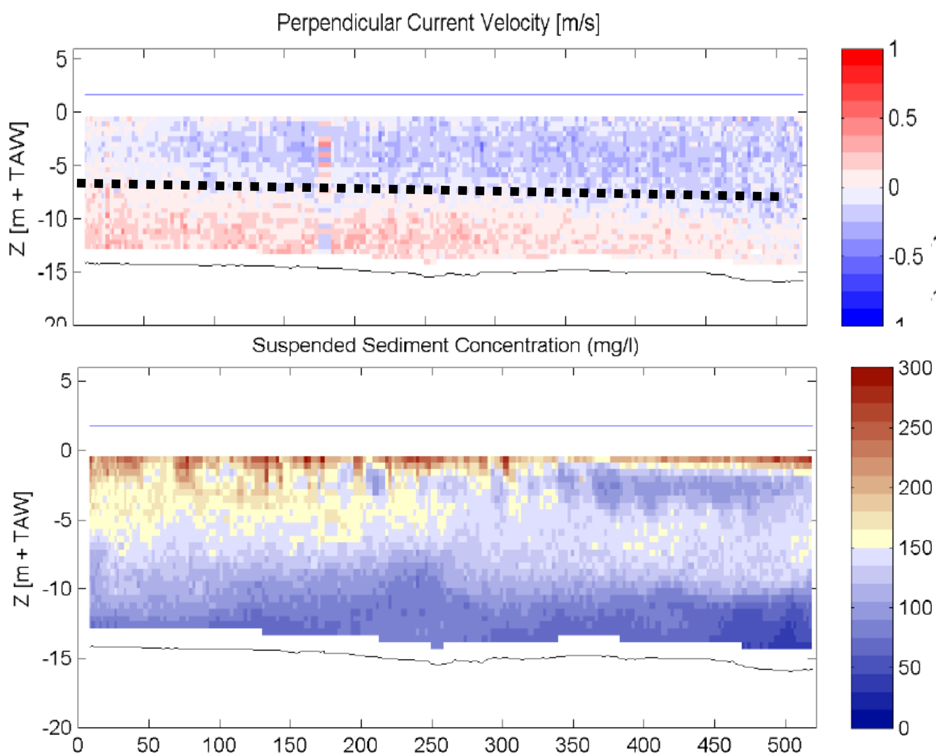
Salinity – Density Currents



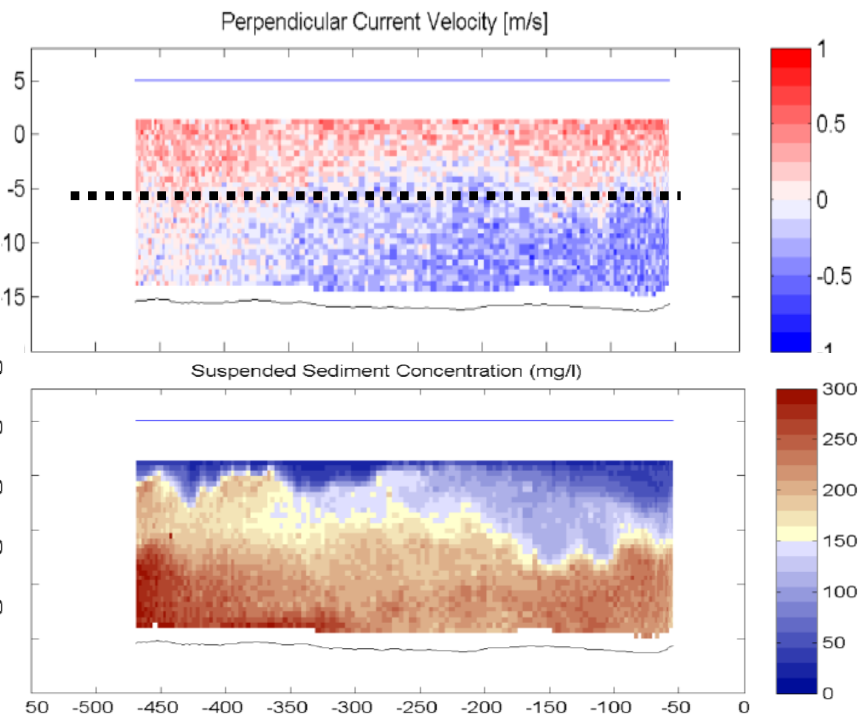
Deurganck dock

ADCP measurements IMDC: vertical profile along entrance

Low water



High water



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Panama Locks – Density currents

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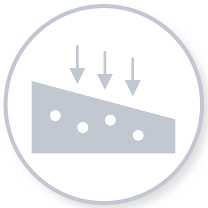
Panama Locks – Density currents

Types of hydrodynamic loads on marine infrastructure

Tidal currents



Density currents

Global circulation currents

Wind-driven currents

Waves

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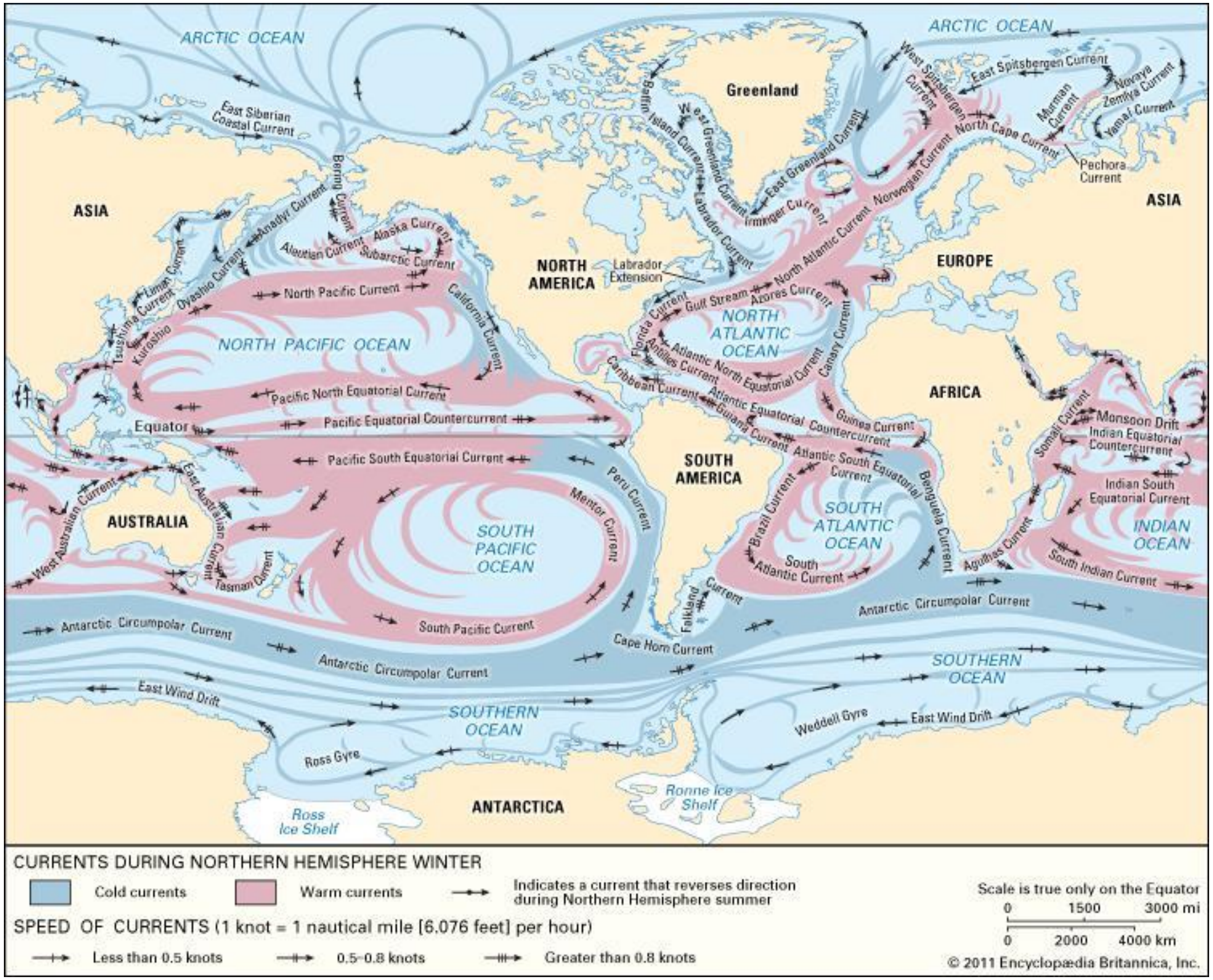
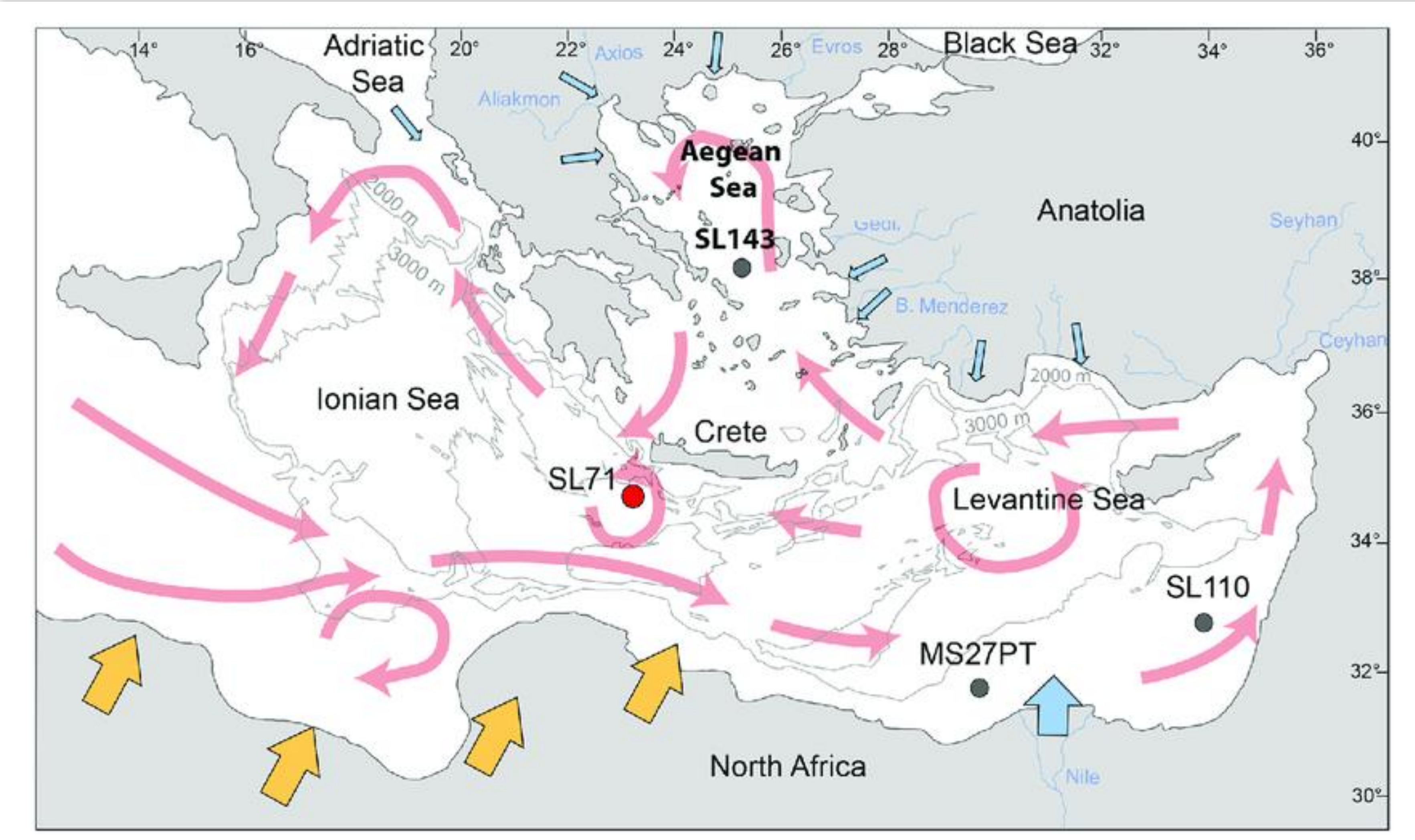
Global circulation currents



Global circulation currents (Eastern Mediterrenian)

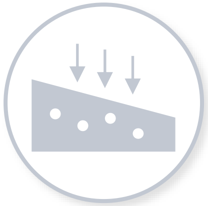


Global circulation currents

- Important in absence of other strong currents
- Usually weak (< 0.5 m/s)
- Strong enough to transport:
  - Dredging plumes
  - Thermal plumes
  - Sewerage outfall
  - Deep sea mining plumes

Types of hydrodynamic loads on marine infrastructure

Tidal currents



Density currents

Global circulation currents

Wind-driven currents

Waves

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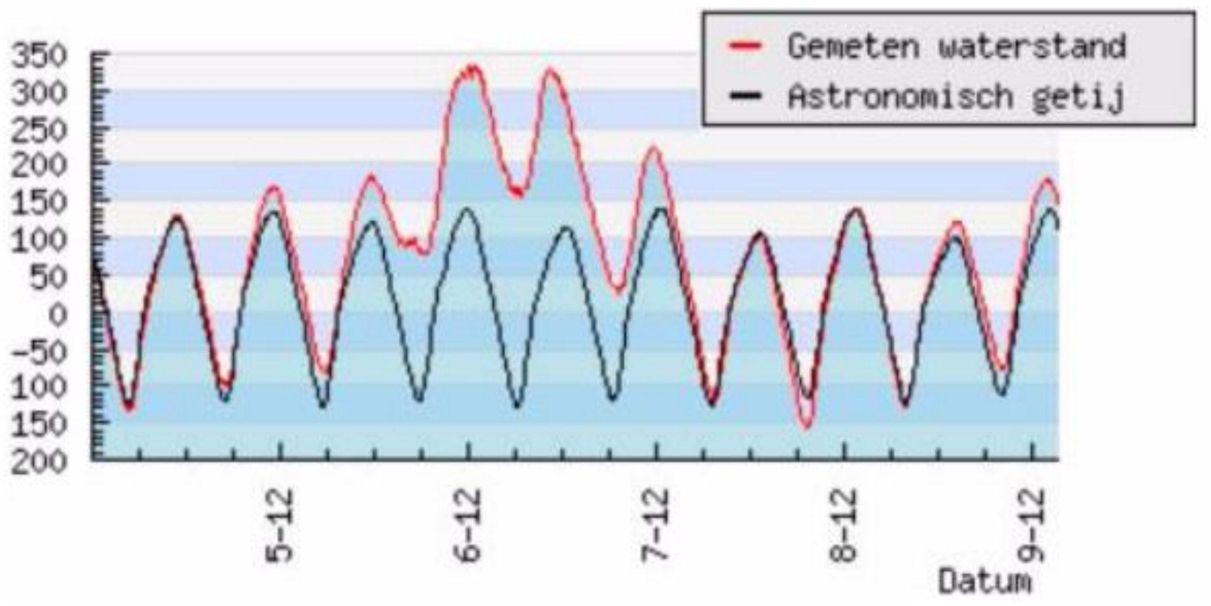
Wind-driven currents

- Wind shear at water Surface
- Induce mixing
- Important when low tidal forcing
- Wind setup during storms
- Langmuir circulations

http://scholarcommons.usf.edu

Wind-driven currents

- Wind setup



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Types of hydrodynamic loads on marine infrastructure

Tidal currents

Density currents

Global circulation currents

Wind-driven currents

Waves

Waves

Main characteristics

Different type of waves

Wave statistics

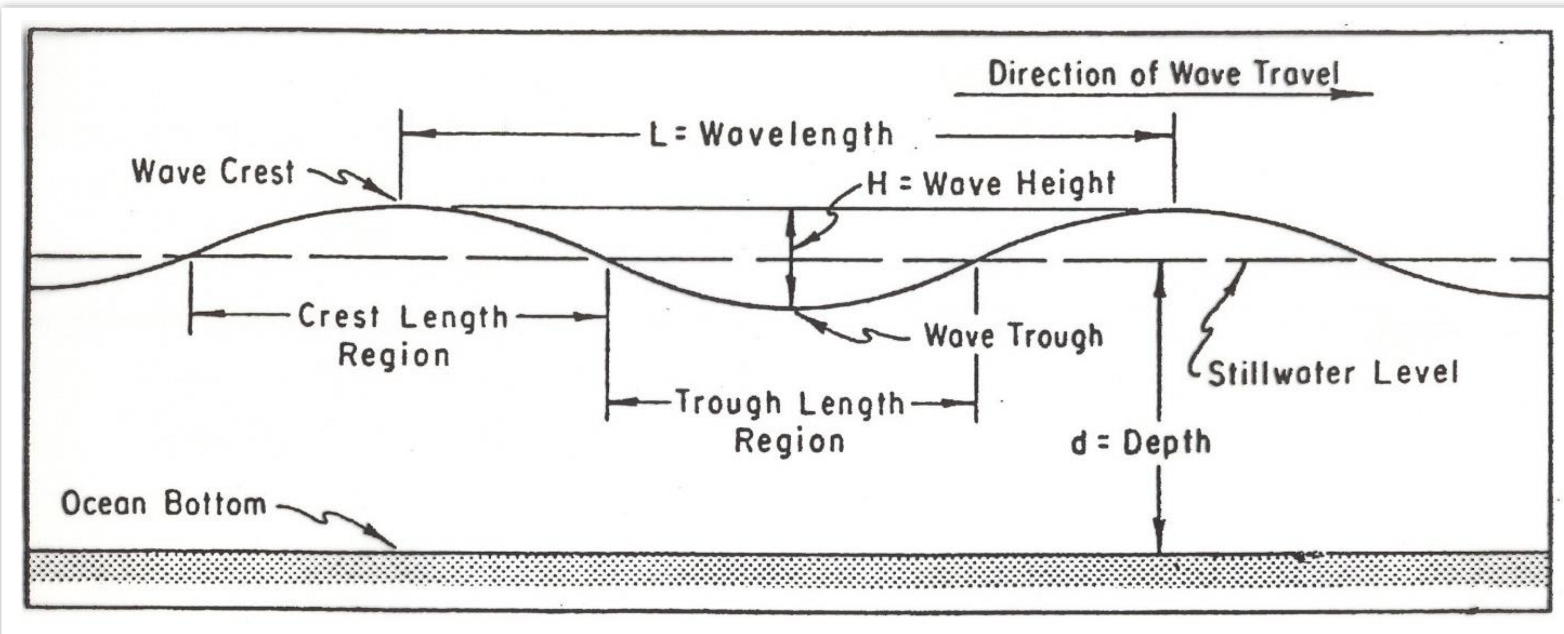
Generating waves

Refraction/diffraction of waves

Measuring techniques

Wave characteristics

- Wave height
- Wave amplitude
- Wave length
- Wave period
- Wave speed
- Wave direction



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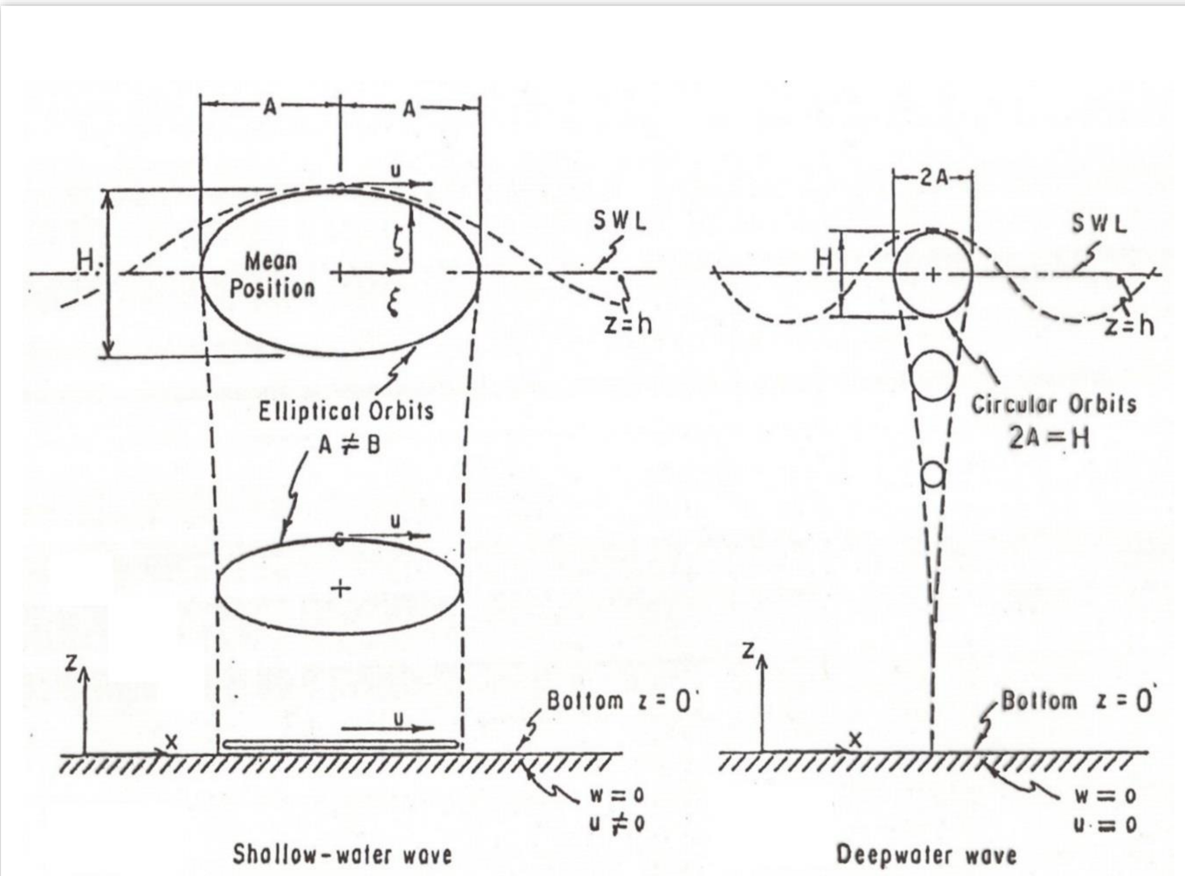
Short and long waves

- Based on wave length compared to water depth
- Short waves (deep water small wavelength):
  - Wave velocity depends on frequency (dispersive)
  - Strong vertical motion (orbital motion)
- Long waves
  - Wave velocity depends on water depth
  - Week vertical motion

quantity	symbol	units	deep water ($h > \frac{1}{2}\lambda$)	shallow water ($h < \frac{1}{20}\lambda$)	intermediate depth (all λ and h)
dispersion relation	$\Omega(k)$	rad·s^{-1}	$\Omega(k) = \sqrt{gk}$	$\Omega(k) = k\sqrt{gh}$	$\Omega(k) = \sqrt{gk \tanh kh}$
phase speed	$c_p = \frac{\Omega(k)}{k}$	m·s^{-1}	$\sqrt{\frac{g}{k}} = \frac{g}{\sigma}$	$\sqrt{gh}$	$\sqrt{\frac{g}{k} \tanh kh}$
group speed	$c_g = \frac{\partial \Omega}{\partial k}$	m·s^{-1}	$\frac{1}{2}\sqrt{\frac{g}{k}} = \frac{1}{2}\frac{g}{\sigma}$	$\sqrt{gh}$	$\frac{1}{2}c_p\left(1 + kh\frac{1 - \tanh^2 kh}{\tanh kh}\right)$

Wave characteristics - **Particle displacement**



The water particle displacement is shown for a shallow water wave and for a deep water wave in figure.

In deep water the effect of the waves does not extend down to the bed; in shallow water the water makes an oscillating movement over the entire depth.

Near the surface the water particles describe an elliptical path, near the bottom the water particles make an horizontal oscillating movement.

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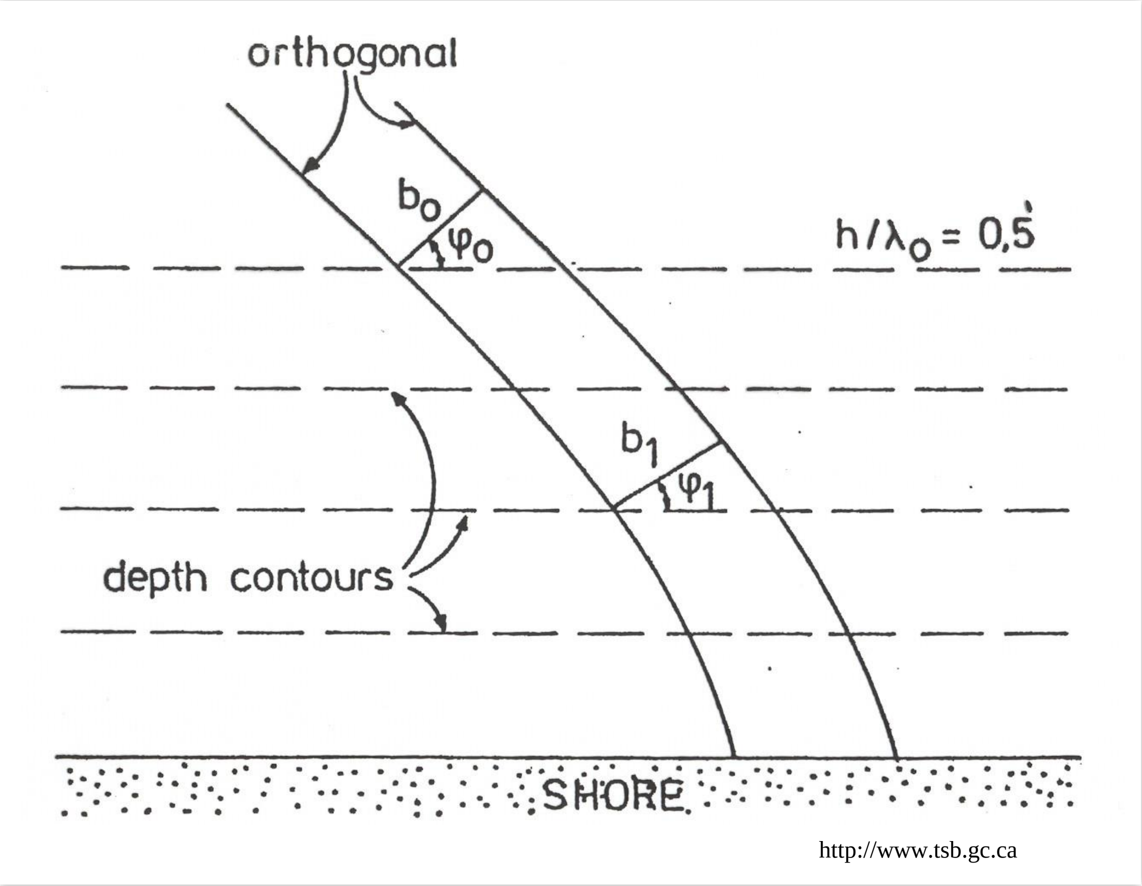
Type of waves

Wave type	Physical mechanism	Periods
Wind waves	Wind shear	<15s
Swell	Wind waves	<30s
Surf beat	Wave groups	1-5 min
Seiche	Wind variation	2-40 min
Harbour resonance	Eigen frequency of basin	2-40 min
Tsunami	Earthquake, submarine landslide	10 min-2 h
Tides	Gravitational action of the moon and sun, earth rotation	12-24 h
Storm surges	Wind stress and atmospheric pressure variation	1-30 days

Wave refraction

Wave refraction over straight parallel contours: waves tend to align with depth contours



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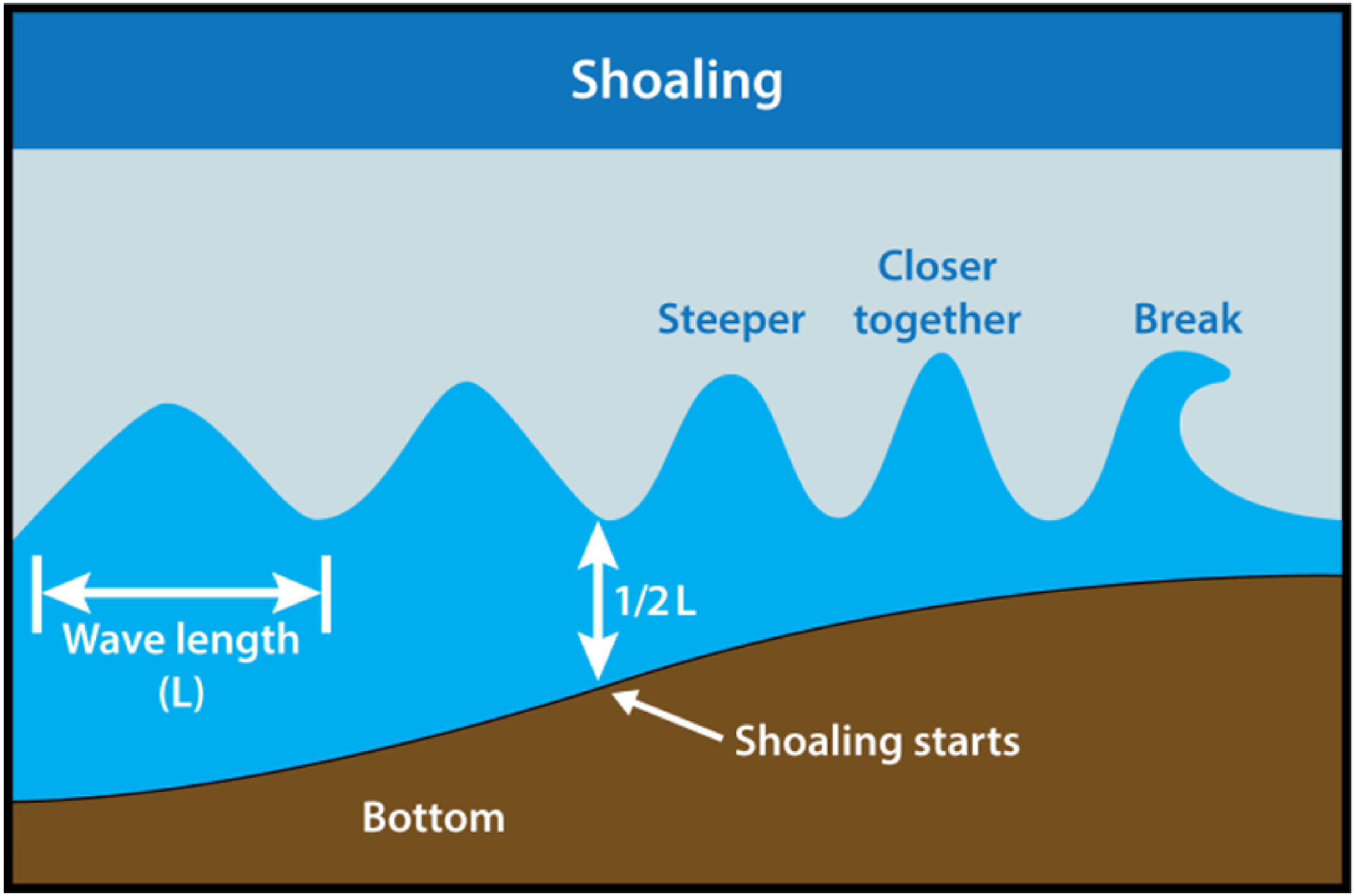
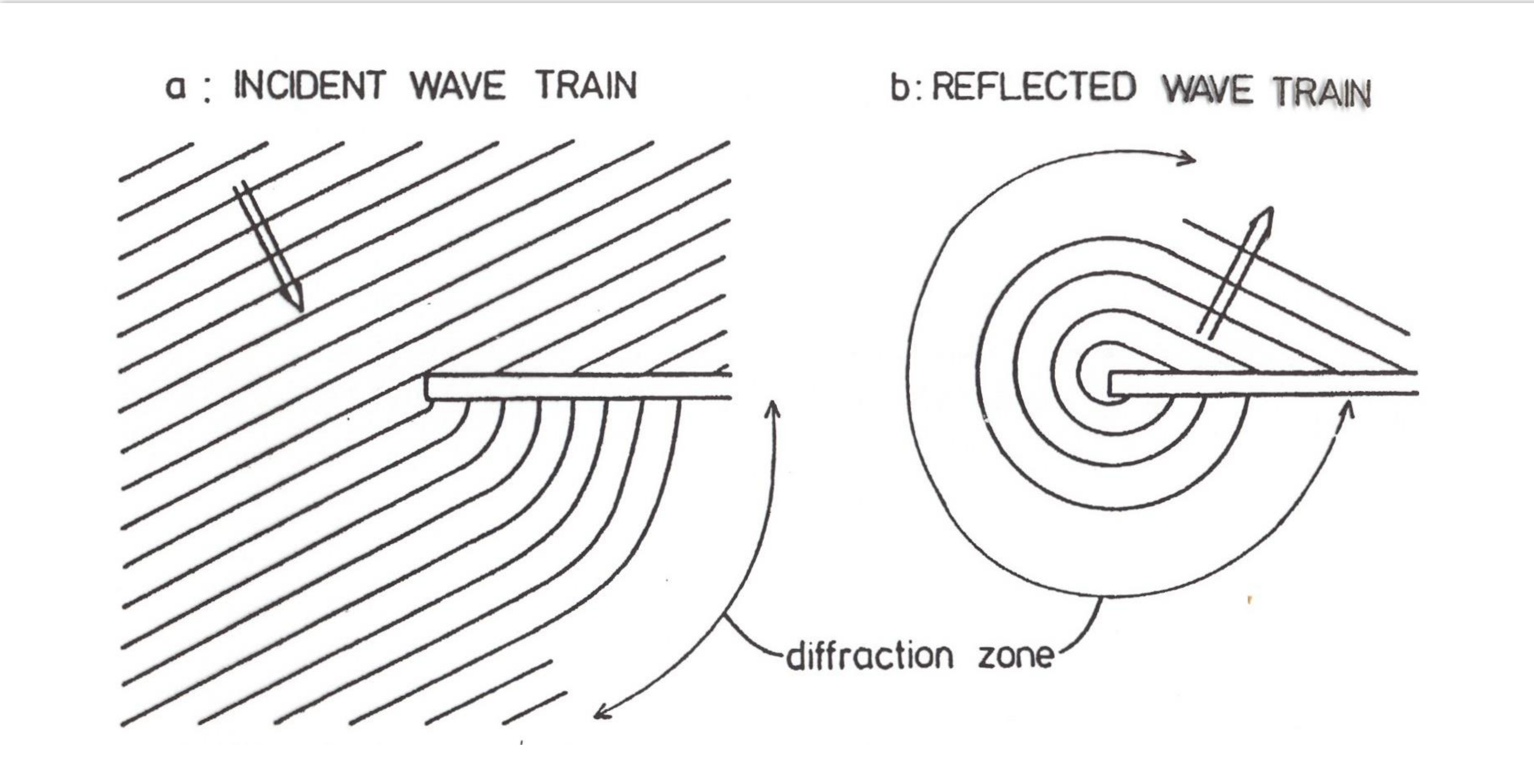
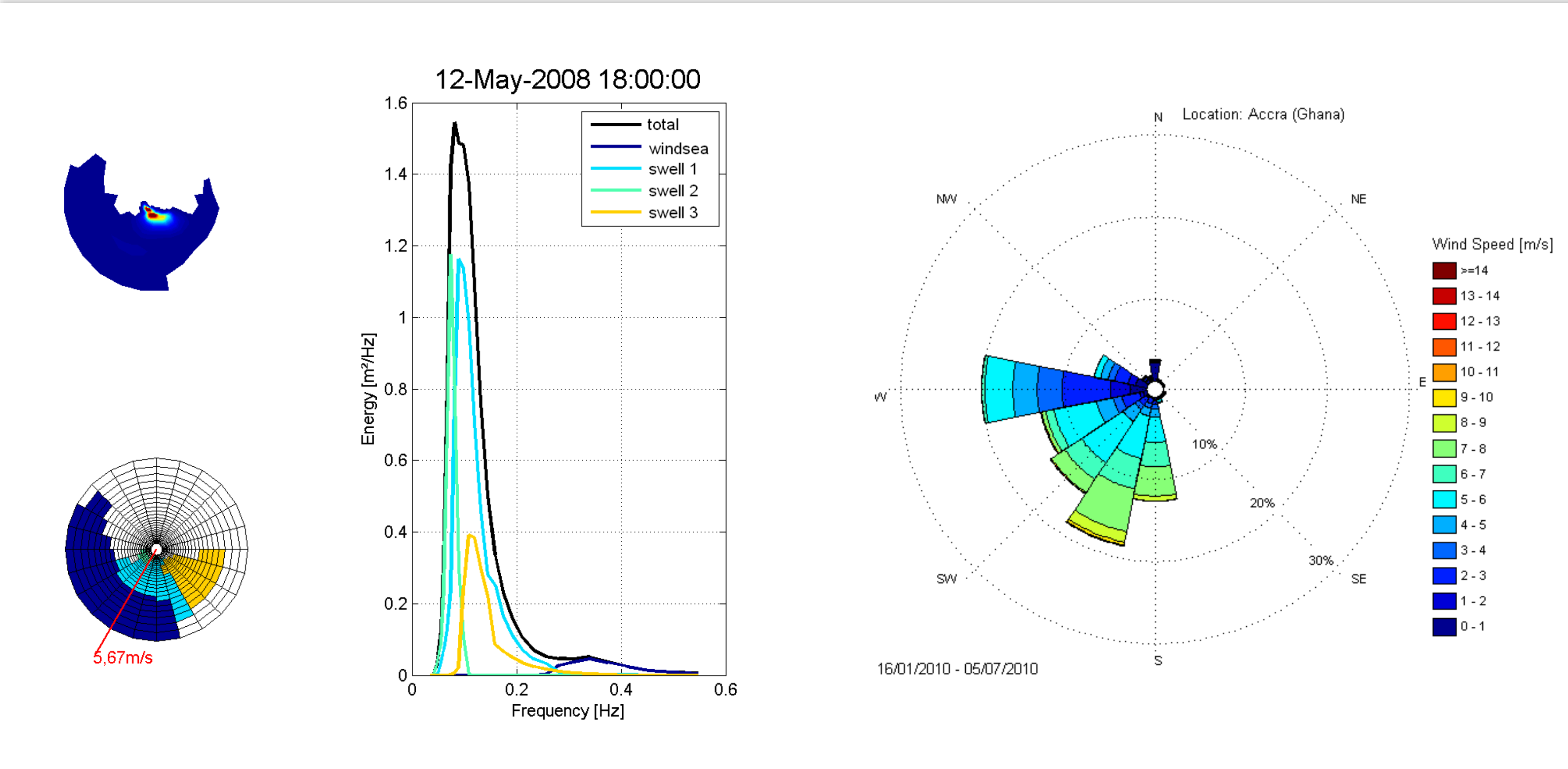
Wave refraction



Wave diffraction



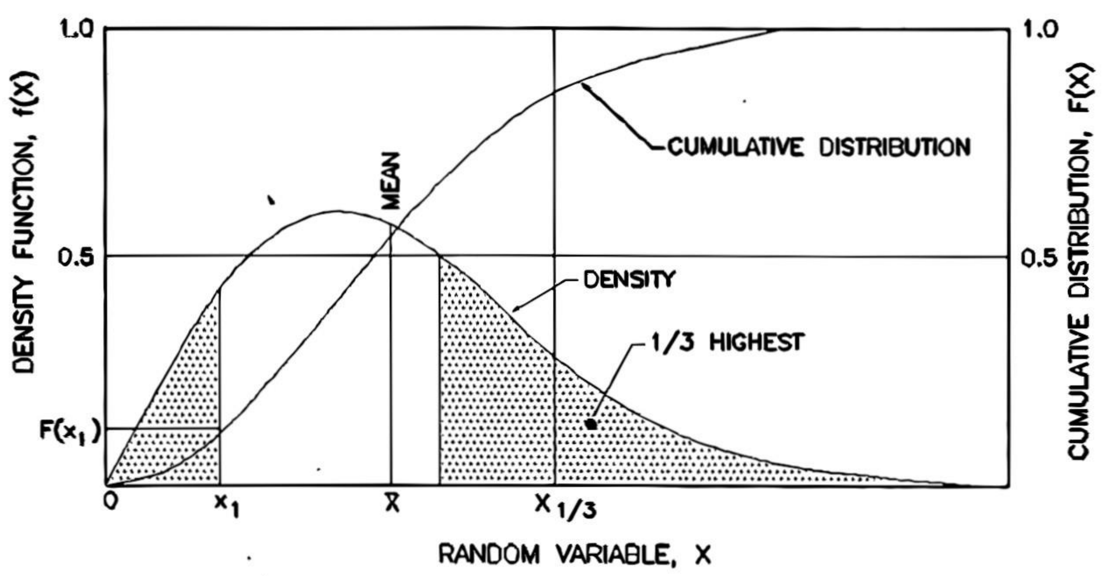
Wave spectrum



Wave statistics

Rayleigh distribution representative for waves

- Significant wave height H_{sign} equals average of ⅓rd of highest waves

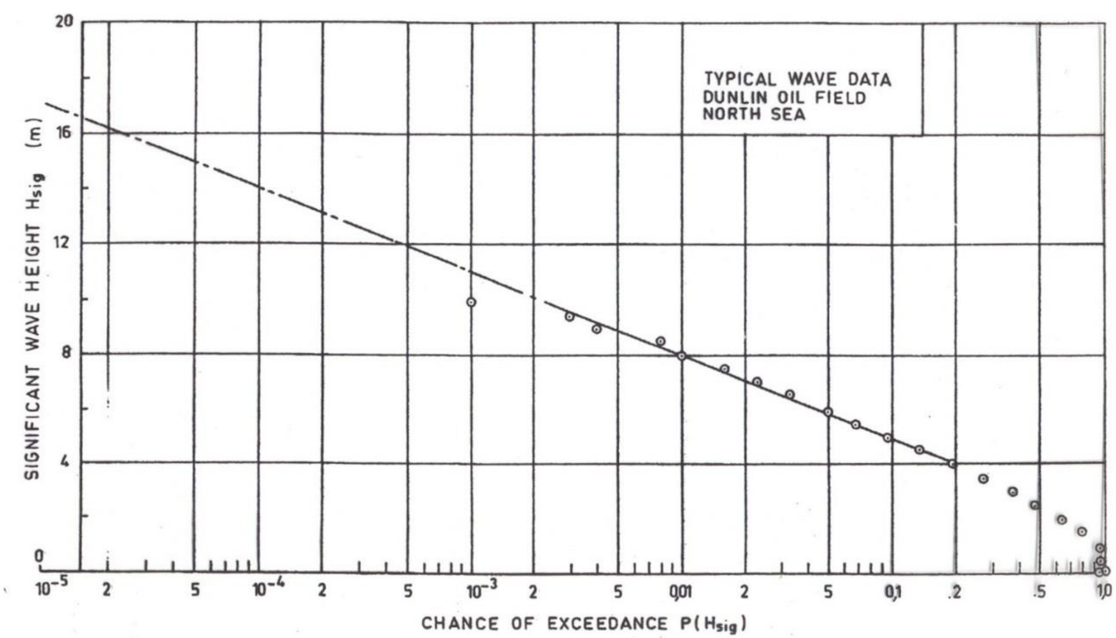


The Rayleigh probability density and cumulative probability distribution

Wave statistics

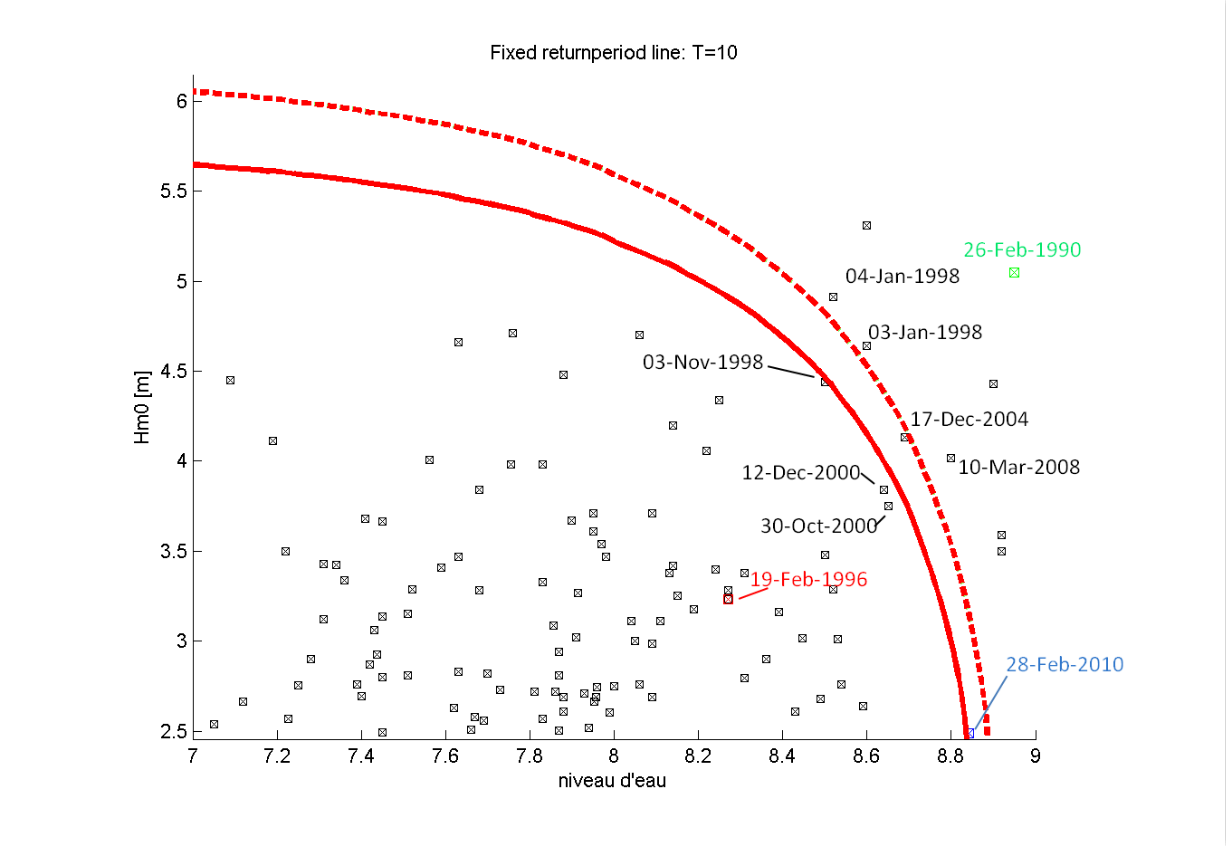
Typical wave data, extreme wave analysis

- Generally registration period 1 – 5 years, exceptionally 10 years
- Extrapolation to design period of 30 – 50 years



Wave statistics

Joint probability of waves and water level



Part 2
Mathematical description

Hydraulic modelling

- The equations governing the dynamics of fluids (Navier-Stokes and Continuity) are highly NON-LINEAR
- The progress of CPU and IT technology (High speed and memory) allows for the solution of mathematical problems that were inaccessible 10-15 years ago.
- An increase in numerical hydrodynamic models used (rivers, lakes, estuaries and coastal areas).

Hydraulic modelling

The equations are, in general,

- Non-stationary (depend on time),
- Non-linear (no analytic solution)
- Of great complexity for turbulent flows.
- Baroclinic: density depends only on salinity and temperature (+sometimes ssc).
- Assuming the fluid is incompressible

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Hydraulic equations

- Depend on two principles:
  - Continuity (mass balance of the fluid)
  - Conservation of momentum (force balance of the fluid; Newton second's law)
  - Driving forces
    - pressure gradient
    - fluid viscosity
    - Body forces: (Coriolis force, gravity, tidal attraction of the sun and moon)

Momentum equations for an incompressible fluid

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho_0}\frac{\partial p}{\partial x}+\frac{\mu}{\rho_0}\nabla^2 u$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho_0}\frac{\partial p}{\partial y}+\frac{\mu}{\rho_0}\nabla^2 v$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho_0}\frac{\partial p}{\partial z}+g_i+\frac{\mu}{\rho_0}\nabla^2 w$$

Or:

$$\rho\frac{Du_i}{Dt}=-\frac{1}{\rho_0}\frac{\partial p}{\partial x_i}+\delta_{i3}g+\frac{\mu}{\rho_0}\nabla^2 u_i$$

Conservation of mass – continuity equation

- Resulting in the general equation of continuity:

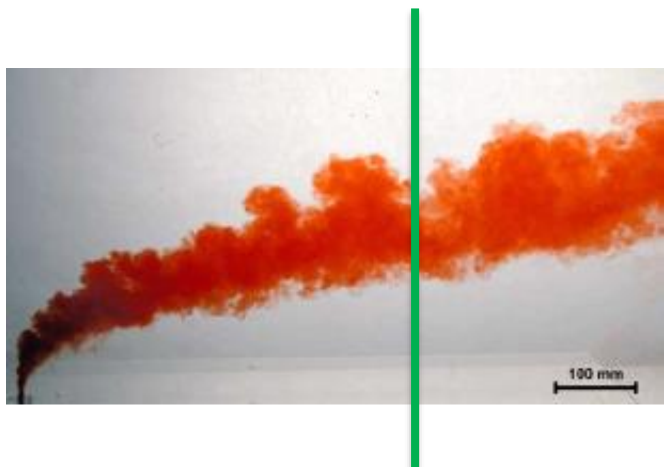
$$\frac{\delta \rho}{\delta t} + \left(\frac{\delta}{\delta x}\rho u + \frac{\delta}{\delta y}\rho v + \frac{\delta}{\delta z}\rho w\right) = 0$$

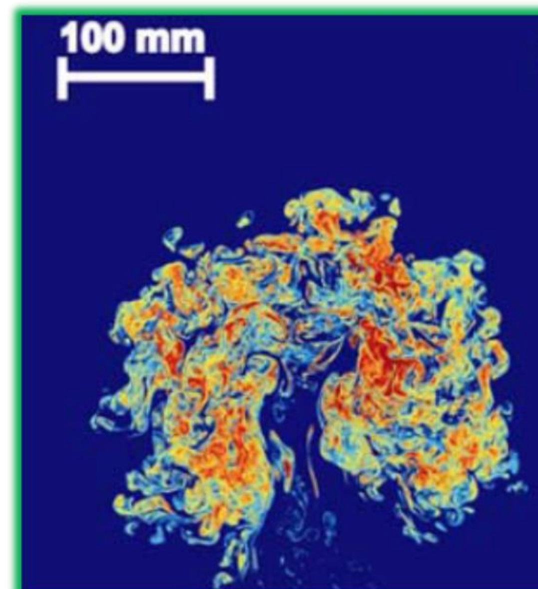
- For incompressible fluids this becomes:

$$\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} + \frac{\delta w}{\delta z} = 0$$

Momentum equations for an incompressible fluid

- Cannot be solved analytically
- Can be directly solved numerically, but only by DNS
- DNS: Solution needed at every dx, with dx < Kolmogorov scale (often sub-millimeter scale)
- Usually not feasible for real-life problems





F.J. Diez et al. / Int. J. Heat and Fluid Flow 26 (2005) 873–882

Part 3
Equations in 1D, 2D, 3D

Types of fluid flow equations

1) Fully three-dimensional
   (3D)
2) Three-dimensional with hydrostatic assumption
   (Quasi 3D)
3) Two-dimensional, averaged over one horizontal dimension
   (2DV)
4) Two-dimensional, depth averaged
   (2DH)
5) One-dimensional profilfe model (1DV)

   One-dimensional, averaged over a river section
   (1D)

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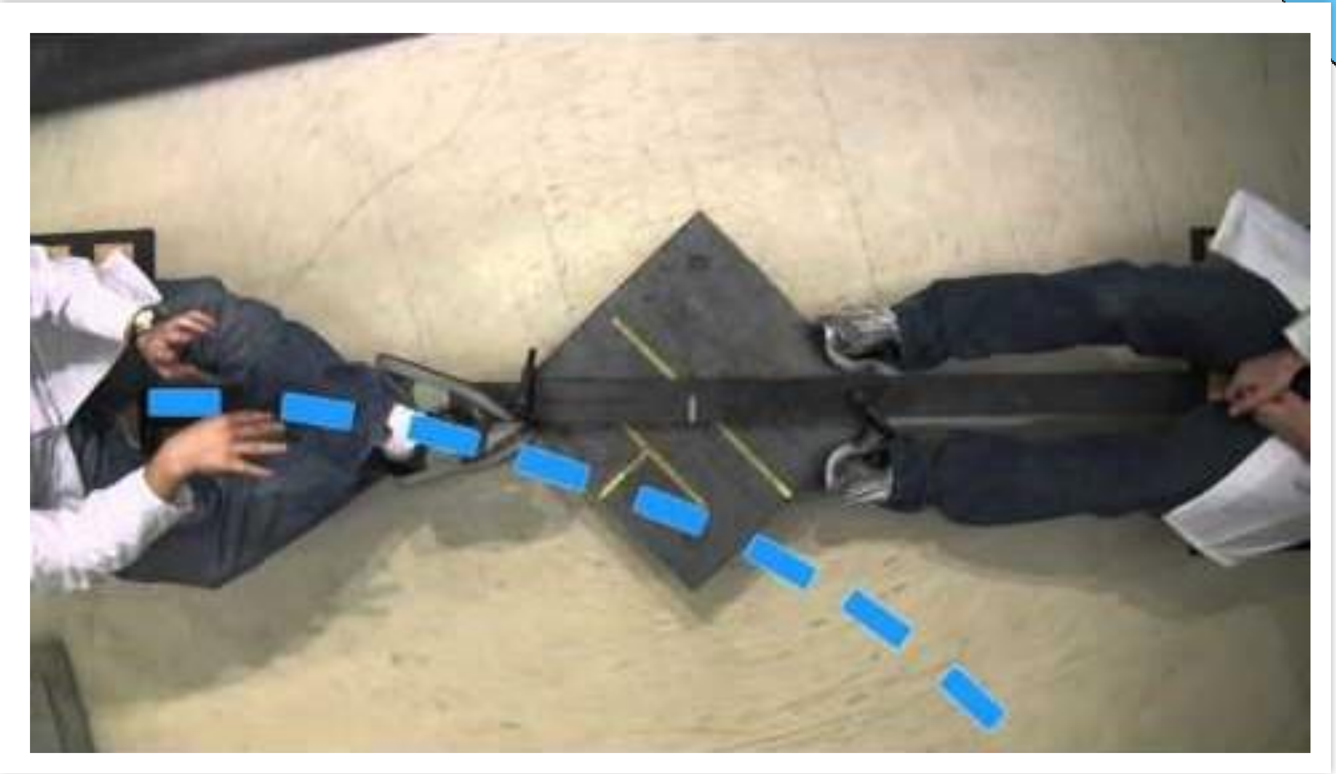
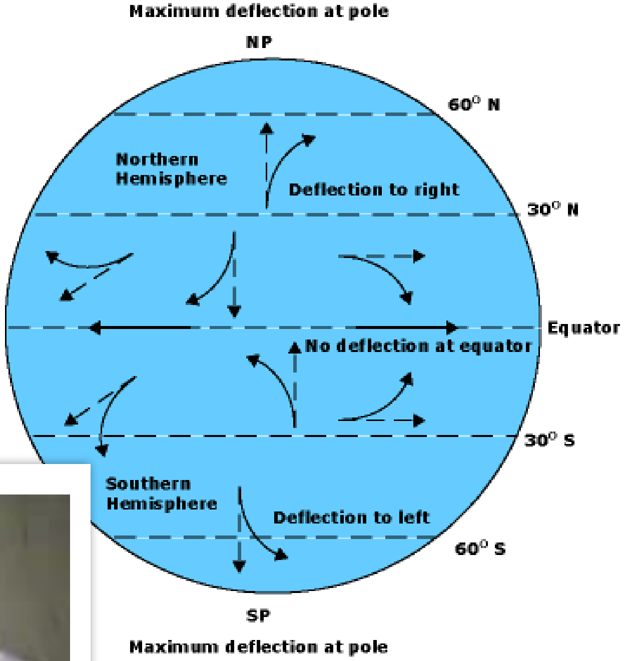
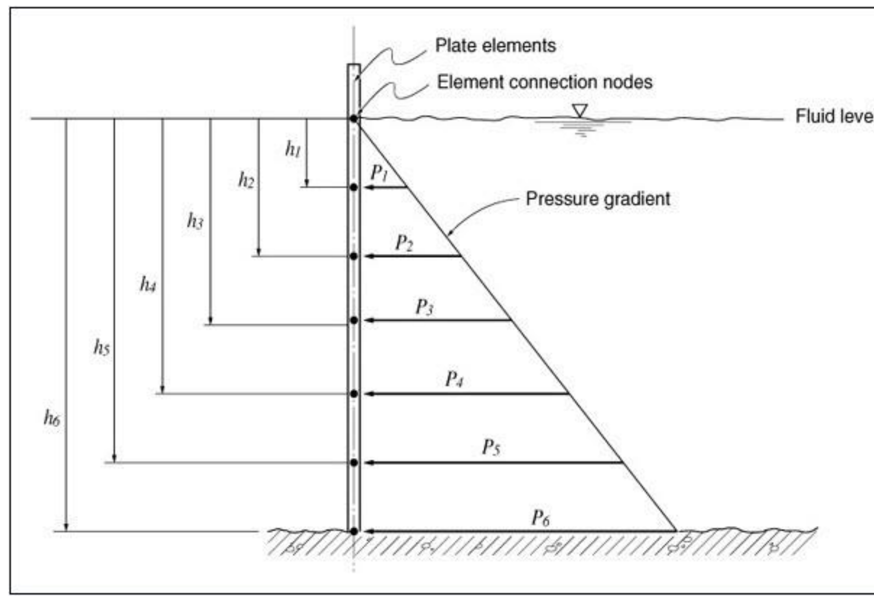
Coriolis force:





Hydrostatic vs non-hydrostatic models

- Non-hydrostatic model:
  - Water pressure depend on flow accelerations
  - Force balance for vertical velocities
  - Large calculation times
  - Needed for problems with strong vertical accelerations (small scale processes)
- Hydrostatic model
  - Water pressure depends on weight of water column only
  - Vertical velocities from mass balance
  - Smaller calculation times
  - Used for large scale problems



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Boundary conditions (vertical)

- Free surface:
  - Shear stress due to wind

$$\frac{\tau_{sx}}{\rho_0} = \upsilon_e \frac{\partial u}{\partial z}_{z=\eta} = C_a U_w \sqrt{U^2{}_w + V^2{}_w} \frac{\rho_a}{\rho_0}$$

- Bottom:
  - Shear stress due to bottom friction (decelerated flow)
  - Different formulation (empirical)
    - Chezy
    - Manning/Strickler
    - Nikuradse
  - Needs a friction coefficient
    - Difficult to different to determine
    - Calibration is needed

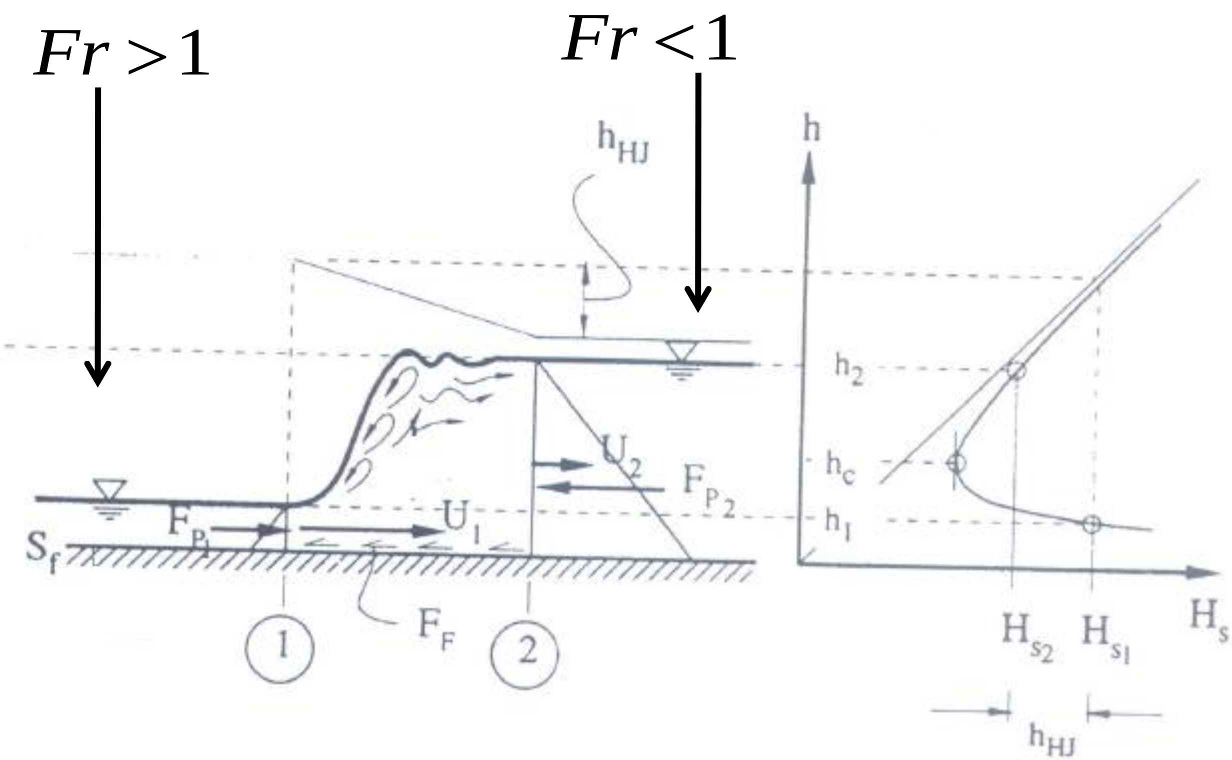
$$\frac{\tau_{bx}}{\rho_0} = \upsilon_e \frac{\partial U}{\partial z}_{z=-h} = \frac{gU\sqrt{U^2+V^2}}{C^2}$$

Boundary condition (horizontal)

- Combination of:
  - Water levels
  - Velocities
  - Flow rates
- Type of depends on the physics of the problem
  - Subcritical/supercritical flow
  - River outflow in coastal model
  - Tidal boundary conditions

Flow in channels

- Hydraulic jump



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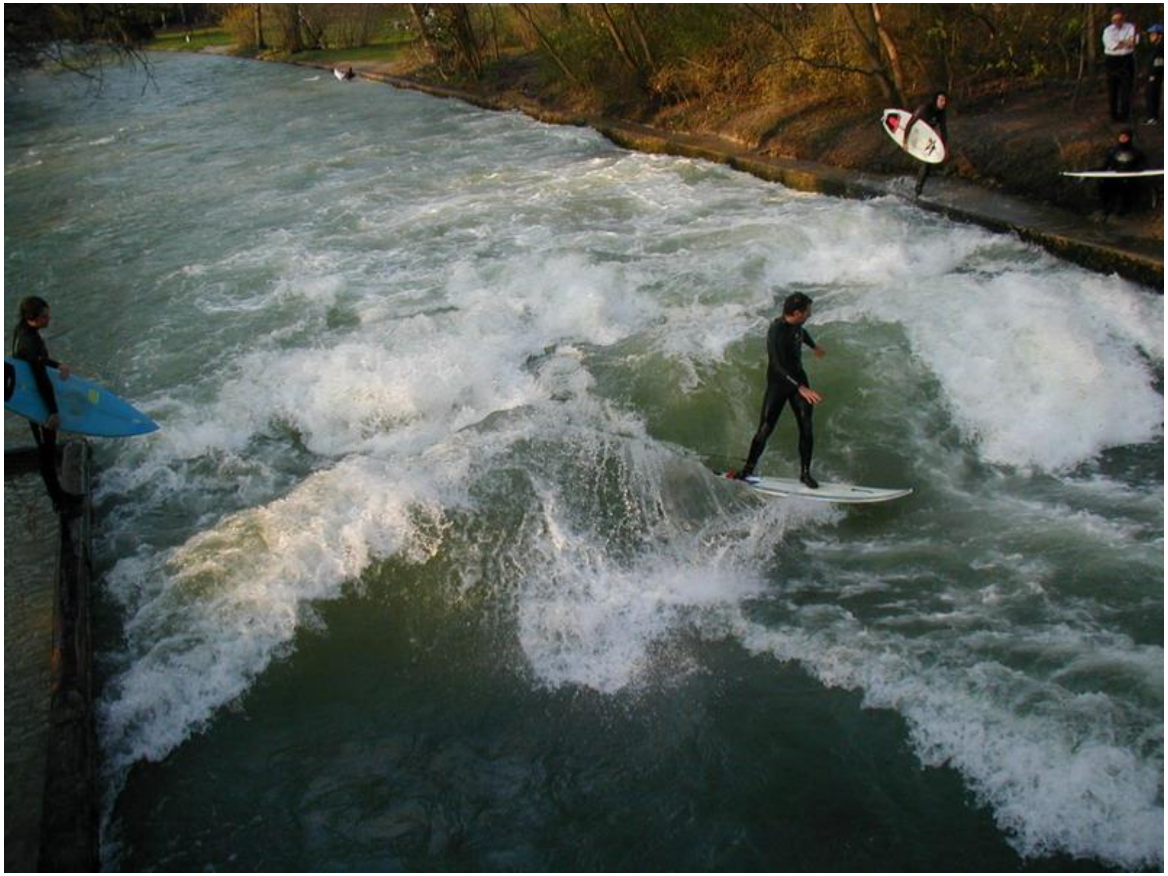
Flow in channels

- Hydraulic jump

Flow in channels

- Hydraulic jump: surfing possible!



2-dimensional, depth averaged (2DH)

Momentum equations:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g\frac{\partial \eta}{\partial x} + g\frac{U\sqrt{U^2+V^2}}{C^2 H} = \frac{C_a \rho_a U_w^2 \cos\psi}{\rho H} + \upsilon_e\left[\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right] + 2\Omega \sin\varphi V$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + g\frac{\partial \eta}{\partial y} + g\frac{V\sqrt{U^2+V^2}}{C^2 H} = \frac{C_a \rho_a U_w^2 \sin\psi}{\rho H} + \upsilon_e\left[\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right] - 2\Omega \sin\varphi U$$

$$p_z = p_{atm} + g\int_z^{\eta} \rho \, dz$$

$$u(z) = U = \text{constant};$$

$$v(z) = V = \text{constant};$$

$$\mathrm{H} = \text{Water depth}$$

$$\eta = \text{Water surface level}$$

Continuity equation:

$$\frac{\partial H}{\partial t} + \frac{\partial UH}{\partial x} + \frac{\partial VH}{\partial y} = 0$$

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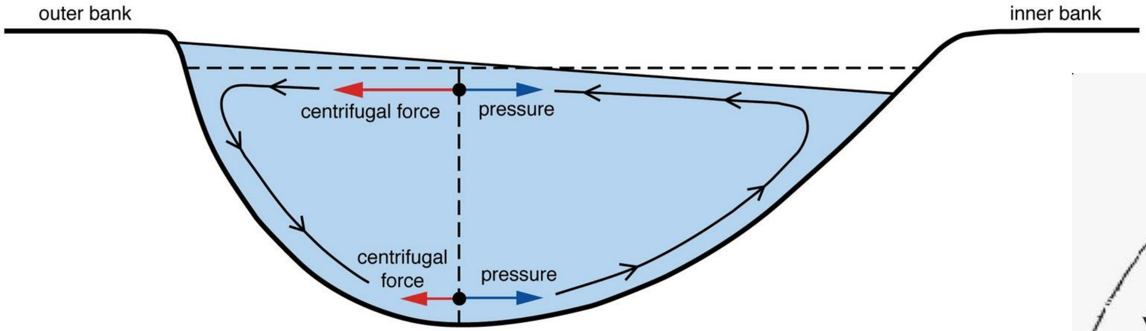
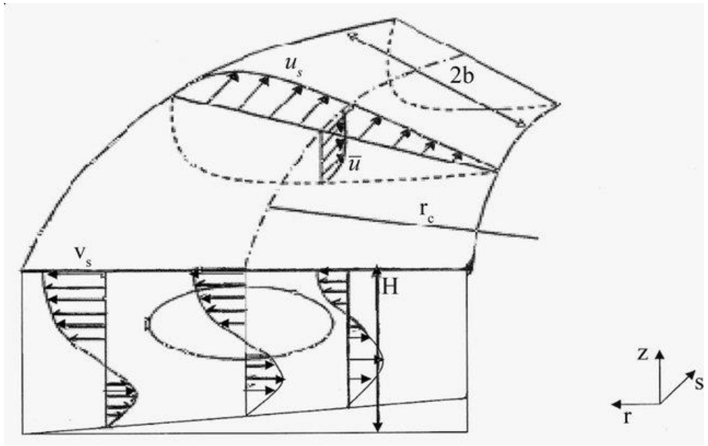
2-dimensional, depth averaged (2DH)

+ Advantage: faster to compute
- Disadvantage: vertical effects neglected: e.g. secondary flow

  → Expert judgement when justified!





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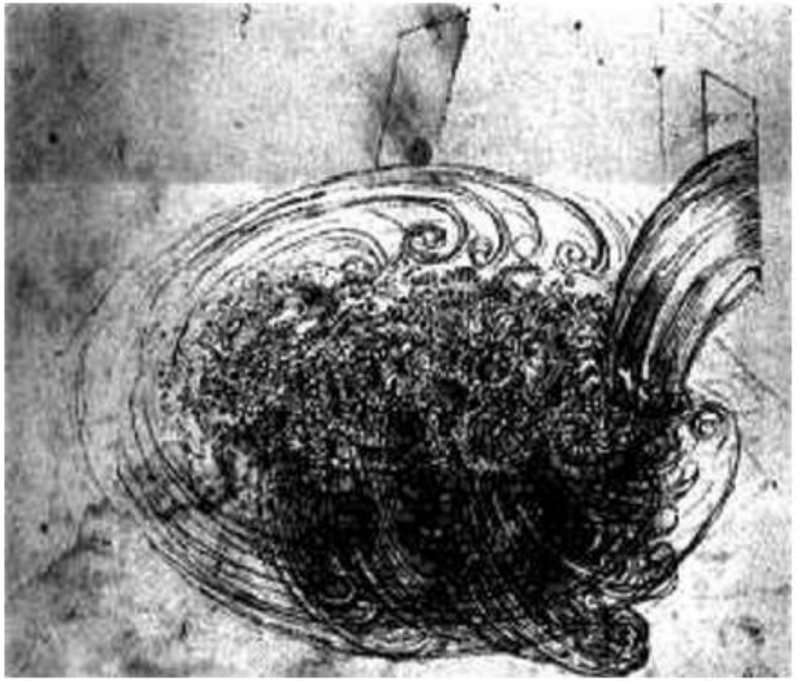
Part 4
Turbulence

Turbulence



(efluids.com)

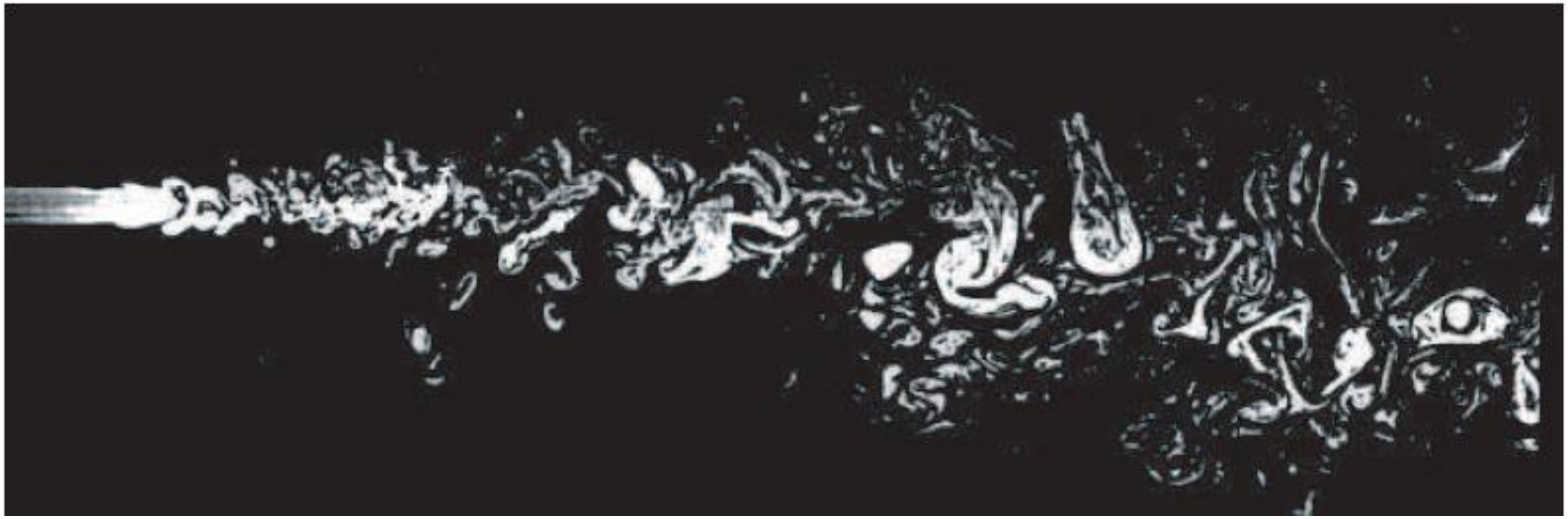
Turbulence

Reynolds number: ratio of inertia to viscous forces

$$\mathrm{Re} = \frac{UD}{\nu}$$ For pipe flow

$$\mathrm{Re} = \frac{UR_h}{\nu}$$ For open channel flow

Turbulence



(from Dimotakis, et. al., phys. Flds., 26 (11), 3185-3192)

Turbulence

Poetic description of turbulence:

"Big whirls have little wirls,
Which feed on their velocity,
And little whirls have lesser whirls,
And so on to viscosity"

(Richardson, 1922)

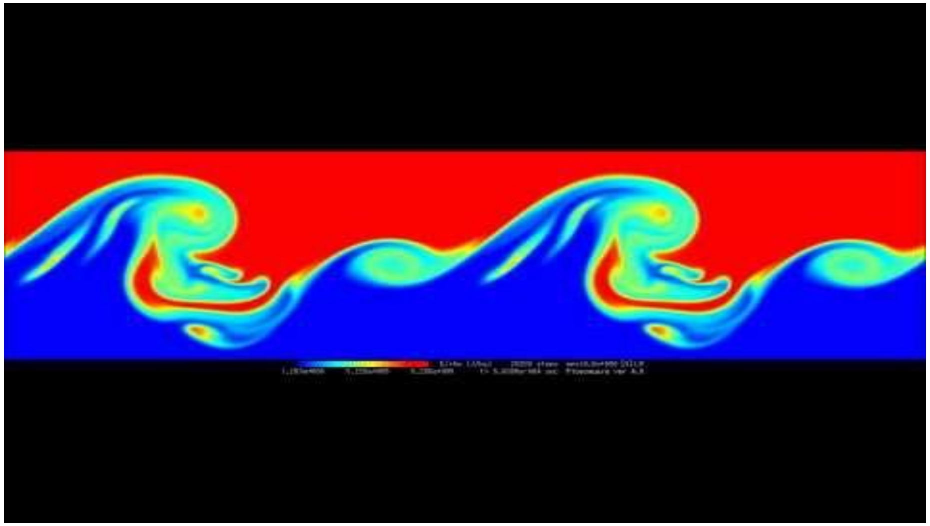
Turbulence

Kelvin-Helmholz instability

(from H.H. Wang, www.asiaa.sinica.edu.tw/~hhwang/)

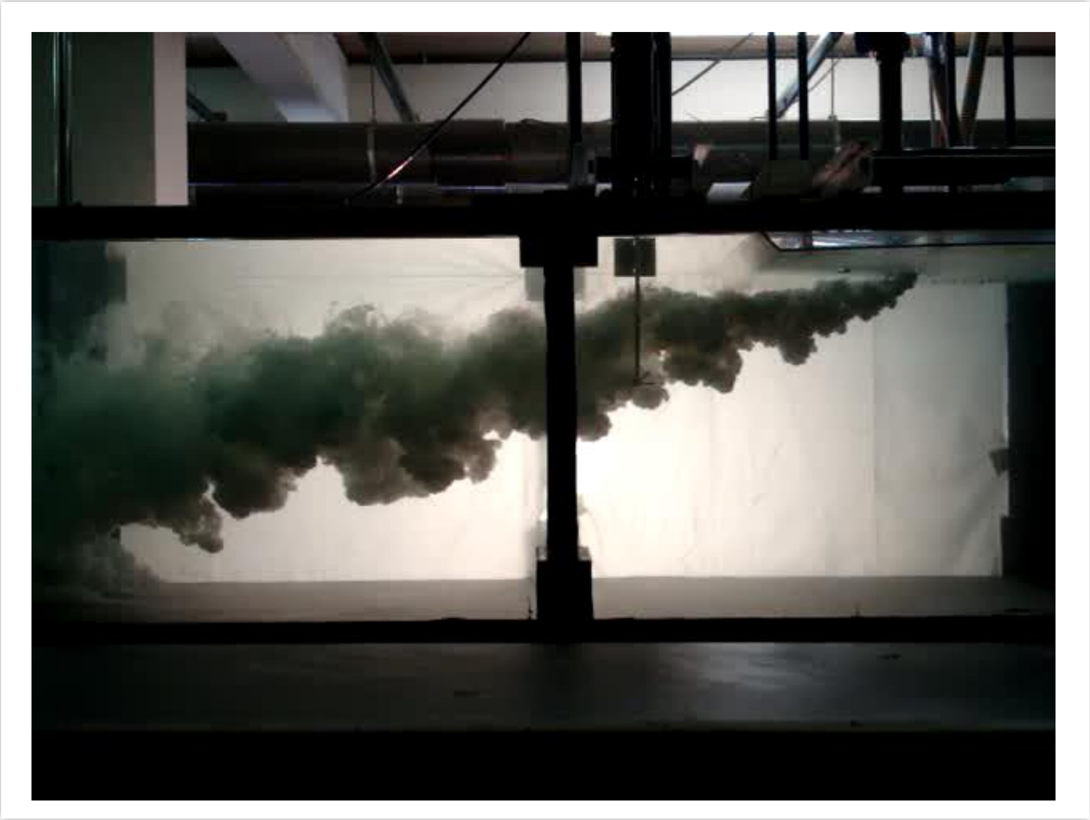
Turbulence

Numerical:



Turbulence

Turbulent sediment plume in crossflow:



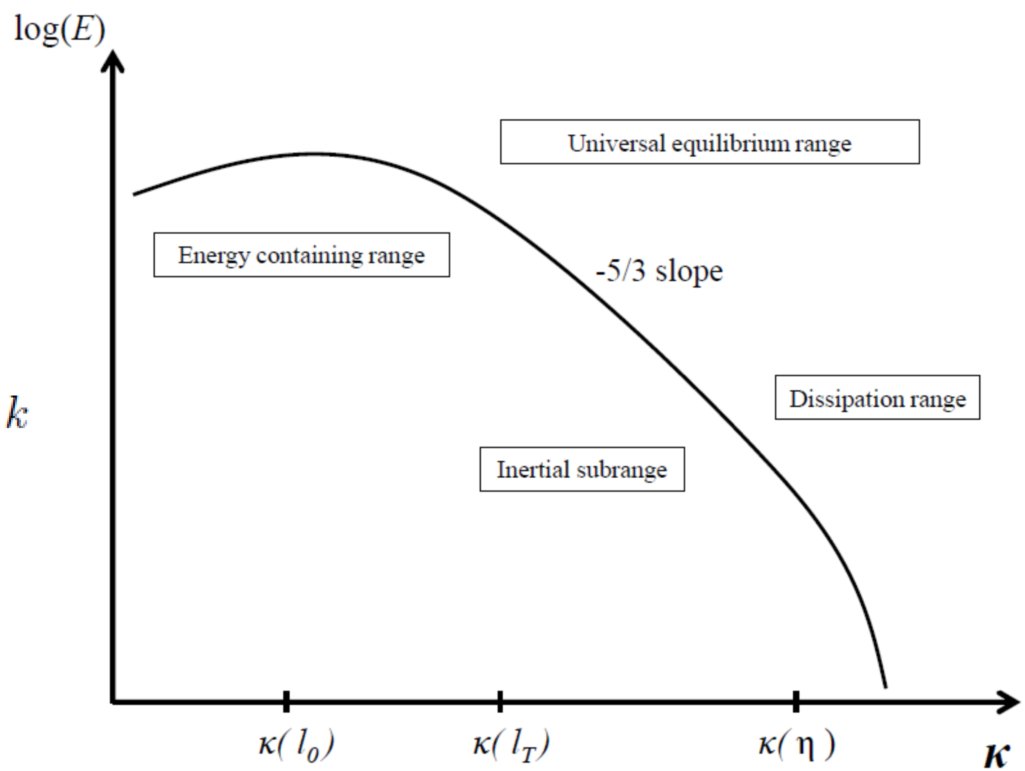
Turbulence

- "Big whirls, little whirls,
- Spectrum of *E*

$$E(\kappa) = c_e \epsilon^{2/3} \kappa^{-5/3}$$

The total turbulent kinetic energy k

$$k = \int_0^\infty E(\kappa)\, d\kappa$$



Real-life problems: 100m 1m 0.01m 0.001m

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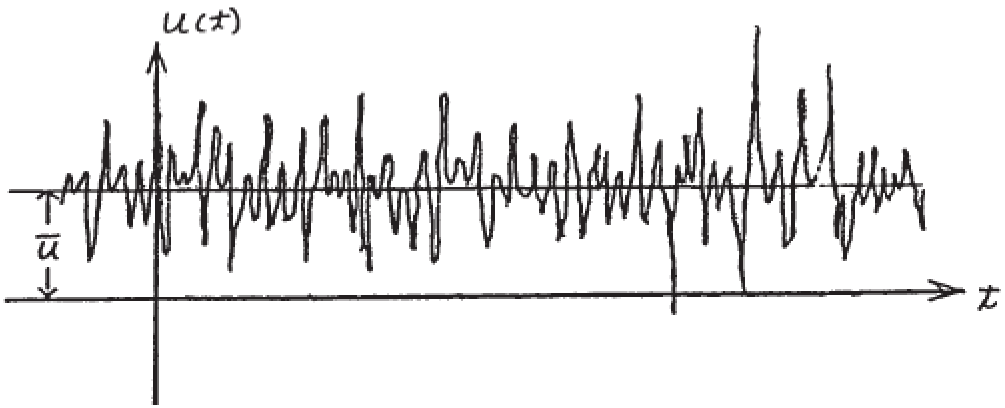
Reynolds averaging



Average over fast turbulent fluctuations

Reynolds-averaged equations

Reynolds hypothesis: $u = U + u'$

Reynolds averaging:

$$\overline{u_i \frac{\partial u_j}{\partial x_i}} \Rightarrow \overline{\frac{\partial u_i u_j}{\partial x_i}} \Rightarrow \overline{\frac{\partial (U_i + u_i')(U_j + u_j')}{\partial x_i}}$$

$$\Rightarrow \frac{\partial}{\partial x_i}(U_i U_j + \overline{u_i' U_j} + \overline{U_i u_j'} + \overline{u_i' u_j'})$$

$$\Rightarrow U_i \frac{\partial U_j}{\partial x_i} + \frac{\partial}{\partial x_i}(\overline{u_i' u_j'})$$

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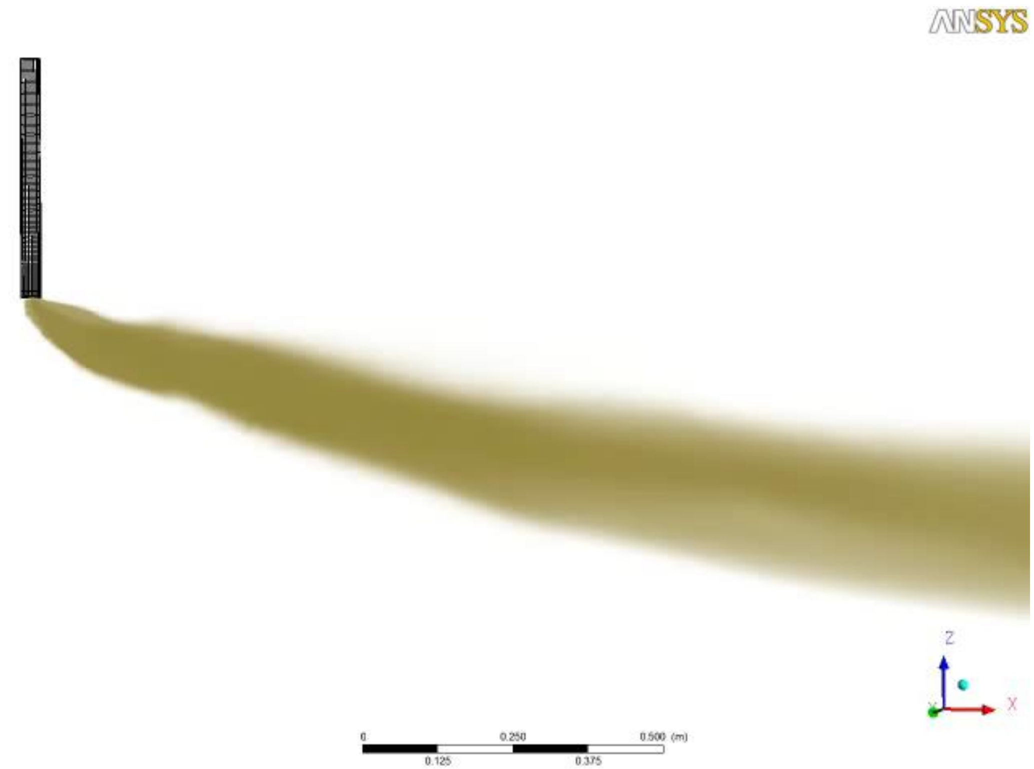
Turbulence closure models

- Eddy viscosity models **(based on time average)**
  - Constant and uniform eddy viscosity
  - k-ε model (energy balance for turbulent energy)
- Reynolds stress model **(based on time average)**
  - Equation for each different turbulent shear stress (slow)
  - Can take anisotropy of turbulence into account
- Large Eddy Simulation (LES; **(based on spatial filtering)**
  - Use very fine grid to resolve the largest eddies
  - Turbulence model only used for smaller scale eddies

- OR: Solve all turbulent structures: Direct Numerical Simulation (DNS)

Turbulence closure models

- Initial: RANS solution
- Time domain: LES



Direct Numerical Solution

- Use extremely fine grid
- Use extremely small time step
- Limited to very small Reynolds numbers

→ Even the smallest eddies are solved by Navier-Stokes equations

→ No sub-grid model needed

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Part 4
Transport of tracers

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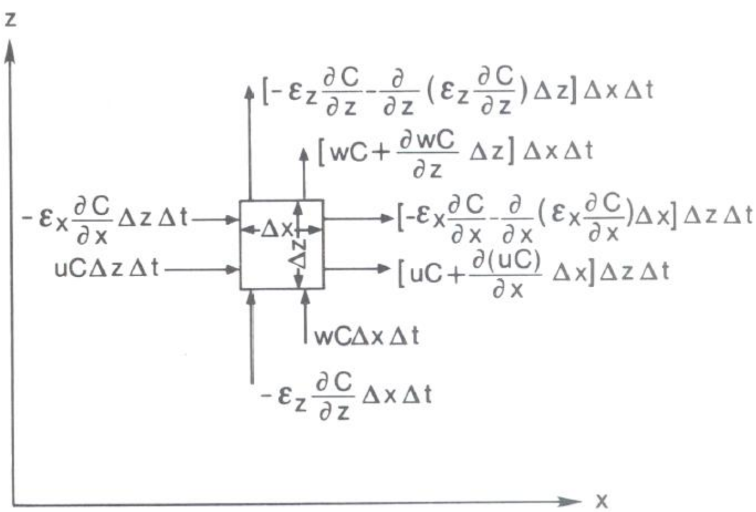
Transport of salt, temperature, bacteria, sediment etc

- **“Mass” balance of advected quantity**
- **Processes:**
  - **Advection**
  - **Diffusion (laminar and turbulent)**
- **Source terms**



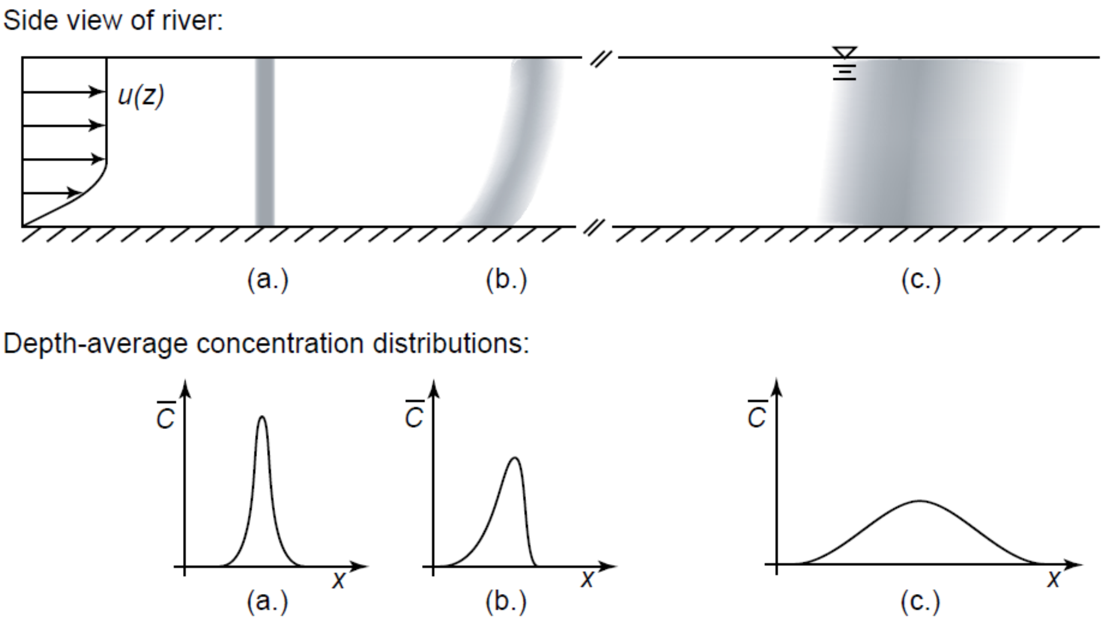
$$\Rightarrow \frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial c}{\partial z}\right)$$

Transport of salt and temperature

2 dimensions, vertical

Example: longitudinal dispersion in rivers:

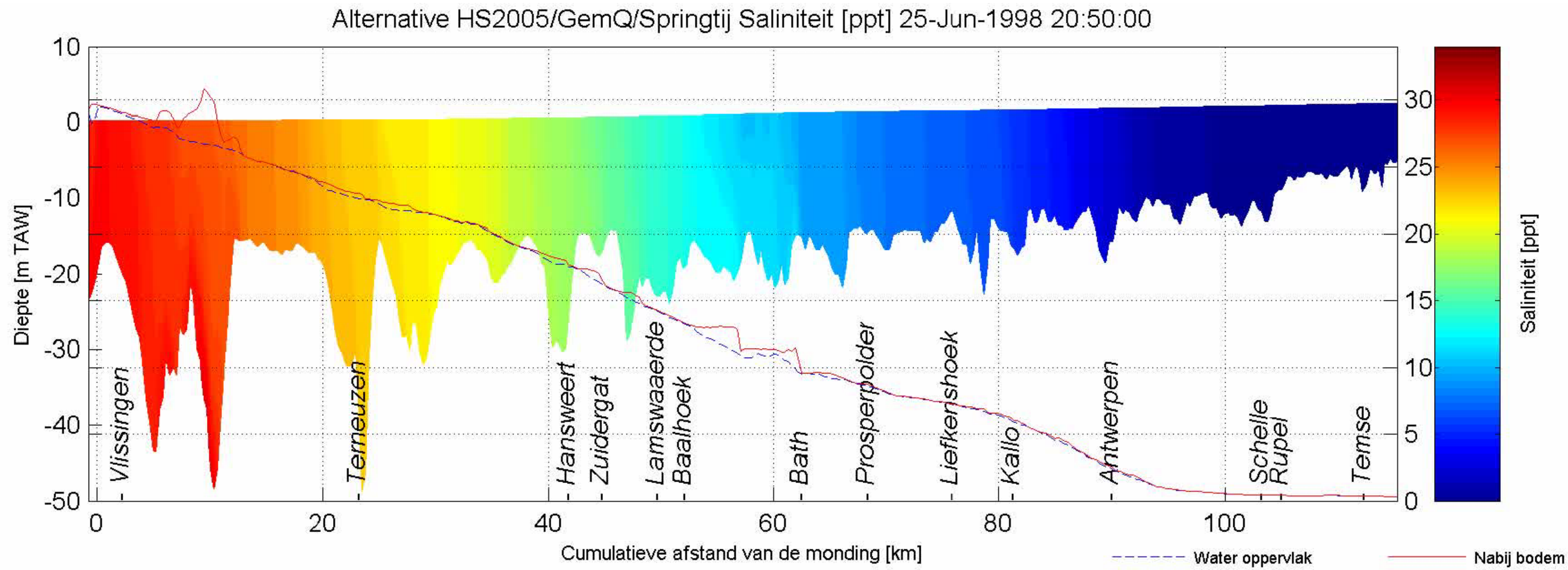
- Salinity
- Temperature
- pollution



From: Socolofsky & Jirka (2005)

Transport of salt and temperature

Salt front in estuaries:



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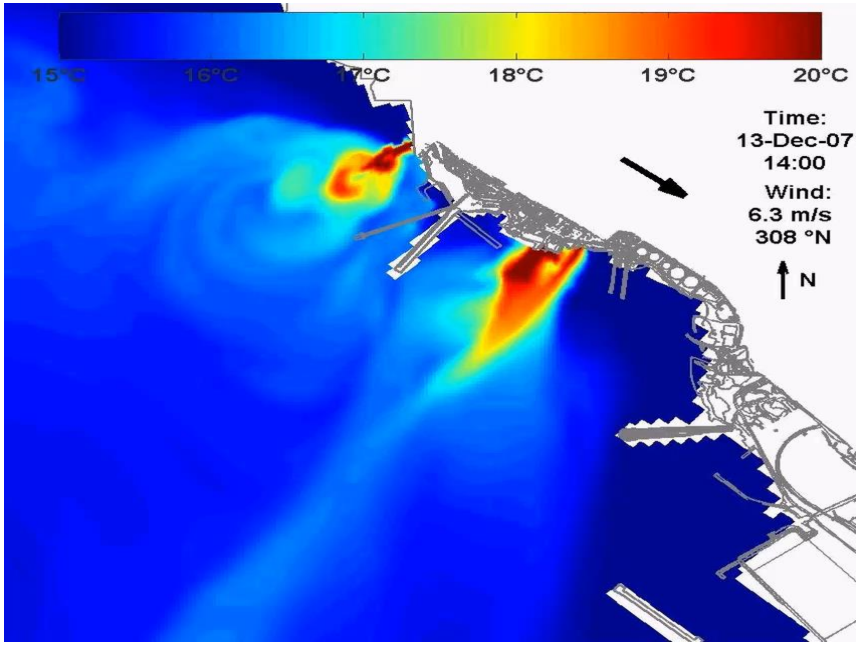
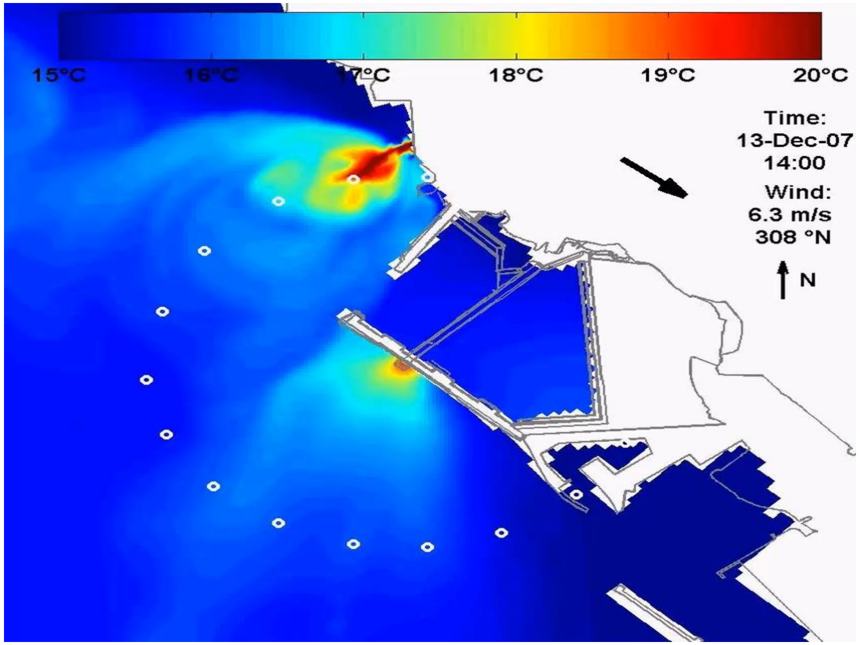
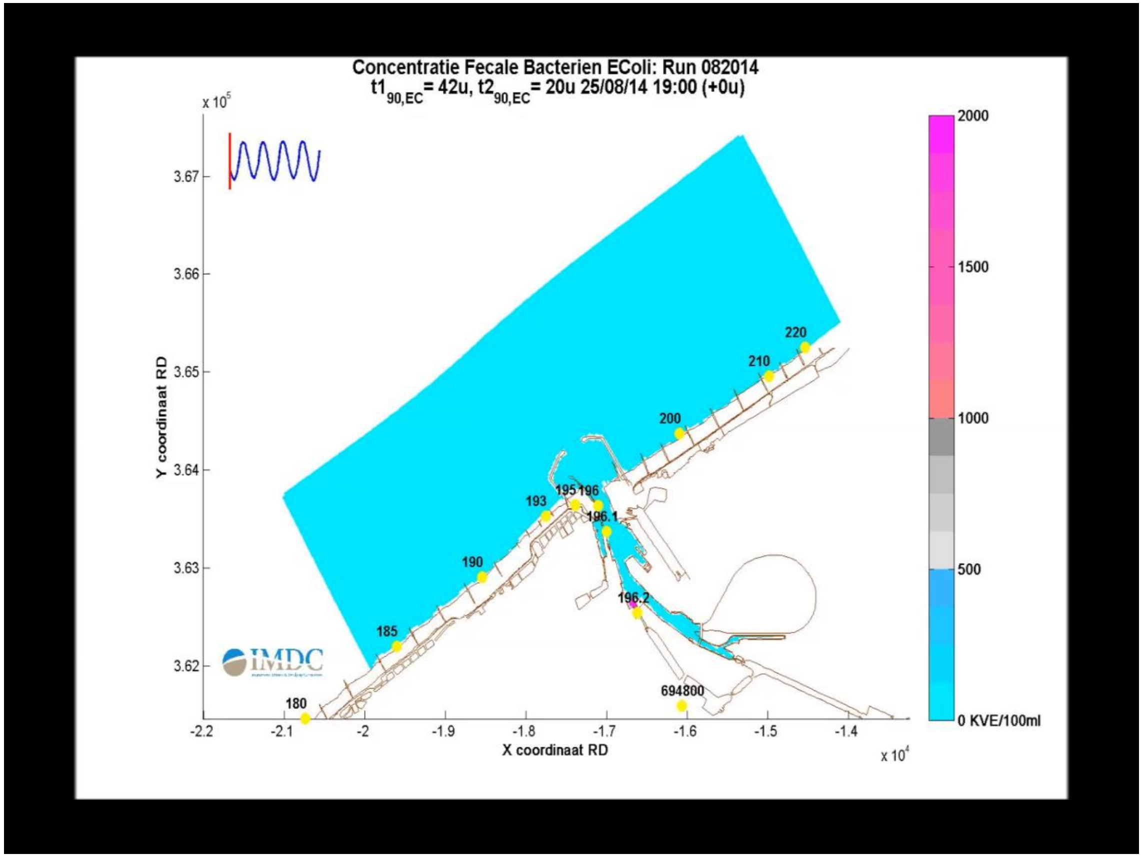
Thermal plume modelling



Thermal plume modelling

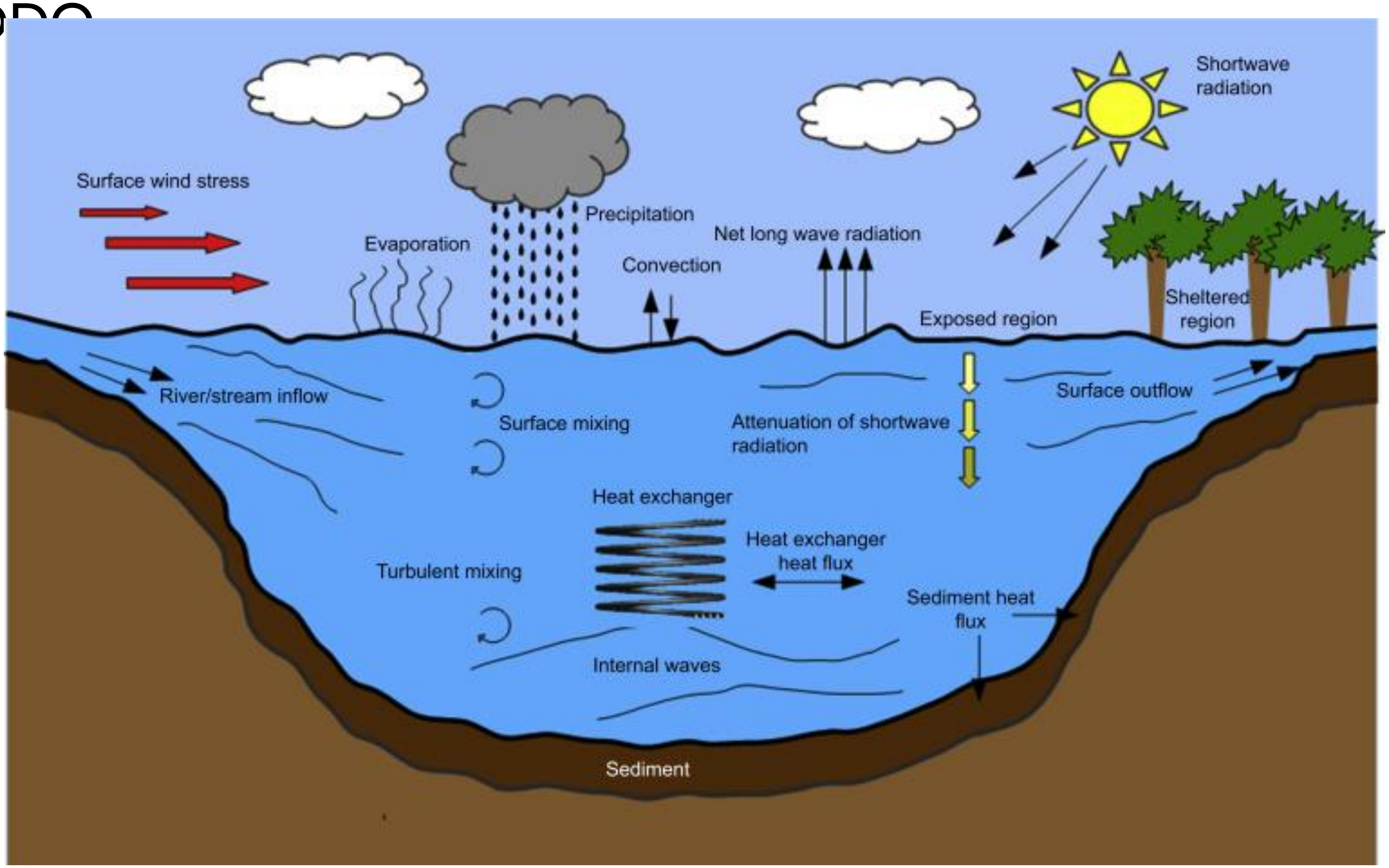


Pollution plume modelling



Thermal heat exchange

- TODO



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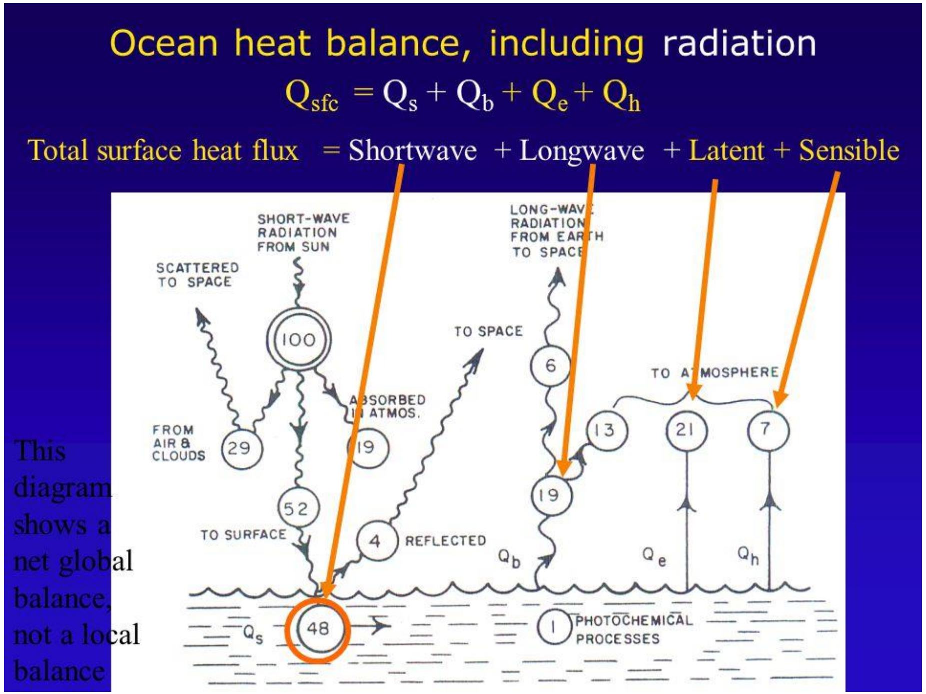
Thermal heat exchange

- Latent heat flux: the flux of heat from the Earth's surface to the atmosphere that is associated with evaporation or transpiration of water at the surface.
- Sensible heat flux: the transfer of heat caused by the difference in temperature between the sea and the air.



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?
ANY QUESTIONS ?
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Lecture 1.2
Introduction to the TELEMAC suite

Alexander Breugem

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Overview of TELEMAC

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What is Telemac?

- A suite of flow simulation software based on the finite element method
- Flow equation are solved on an unstructured (triangular) grid
  - Very flexible
  - Very easy to change resolution to where you need it
- Open source (in fixed format Fortran 90)
- Fully parallel (mpi)

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TELEMAC

- TELEMAC consortium

France, Germany, UK

- Active community
  - Yearly user conference
  - Scientific committee meeting
  - Active forum www.opentelemac.org
- Still many new developments going on
  - New version every year (currently v8.2)

TELEMAC modules

- MASCARET: 1D flow simulation (as InfoWorks, Mike 11)
- TELEMAC 2D: 2D depth-averaged flow simulation (as Mike 21, Delft3D)
- TELEMAC 3D: 3D flow simulation (as Mike 21, Delft3D)
- TOMAWAC: spectral wave modeling (as Swan)
- ARTEMIS: wave agitation in harbours (mild slope equation)
- SISYPHE/GAIA: sediment transport and bed morphology
- NESTOR: dredging simulation
- WAQTEL: water quality parametrizations
- KHIONE: sea ice modelling

- This course, we will mainly look at TELEMAC 3D and WAQTEL

TELEMAC2D/3D

- TELEMAC 2D
  - Shallow water equations
  - Bousinesq equations
  - Finite element method/Finite volume method
  - Transport of tracers (sediment, temperature, salinity)
  - Parametrization of structures (culverts etc)
- TELEMAC 3D
  - 3D shallow water equations
  - Hydrostatic/Non-Hydrostatic
  - Finite element method
  - Transport of tracers (sediment, temperature, salinity)
  - Parametrization of structures (culverts etc)

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Typical applications

- Estuarine/river/sea hydrodynamic modeling
- Sea bed/river bed morphology
- Water quality modelling
- Less suited for:
  - Detailed/local flow/turbulence calculation (use CFD. e.g. openFOAM)

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TELEMAC2D/3D

- Physical processes
  - Advection
  - Diffusion
  - Turbulence (Smagorinksy, mixing length, k-epsilon)
  - Coriolis force
  - Baroclinic flows: density driven flow
  - Tidal body forces
  - Influence of meteorology (wind, atmospheric pressure)
  - Bottom friction (Manning, Strickler, Chezy, **Nikuradse**)

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TOMAWAC

- Calculation of spectral wave energy balance
- Standalone or coupled to TELEMAC 2D/3D
- Physical processes:
  - Wave growth due to wind
  - Dissipation due to whitecapping, depth induced breaking
  - Non-linear wave interactions (triads and quadruplets)
  - Propagation of wave energy (including wave-current interaction, refraction, shoaling)

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SISYPHE/GAIA

- Calculation of bed level changes (Exner equation)
- Coupled to TELEMAC2D/TELEMAC3D
- Physical processes
  - Sand
    - Transport equations (with or without waves; e.g. Engelund-Hansen, Van Rijn)
    - Bed slope effect
    - Advection-diffusion (local problems)
    - Mixtures of different grain sizes (hiding effect, armouring)
  - Mud
    - Advection-diffusion
    - Consolidation (in the bed)
    - Flocculation
    - Hindered settling
  - Sand-mud mixtures

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NESTOR

- Dredging module
- Coupled to SISYPHE/GAIA
- Functionalities
  - Impact of dredging on morphological development
  - Inclusion of dredging/dumping (different polygons)
  - Calculation of dredging volumes
- Note, not suitable for dredging plume simulations

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WAQTEL

- Water quality module
- Coupled to TELEMAC-2D/3D
- Provides boundary conditions/source terms for advection-diffusion equation:
- Processes:
  - Water temperature
  - Dissolved oxygen
  - Biomass (algae)
  - Micro-pollutants (radio-elements or heavy metals)
  - Eutrophication (phosphor, nitrogen, biomass)

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Advantages/disadvantages TELEMAC suite

- Advantages
  - Free
  - Unstructured grid
  - Flexible (open source)
  - Fast (fully parallel)
  - Can deal with shocks non-hydrostatic (bores, hydraulic jumps)
- Disadvantages
  - User friendliness:
    - No GUI yet for steering files
    - Documentation not complete/unclear
    - Some things can only be done in Fortran

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TELEMAC NUMERICAL METHOD

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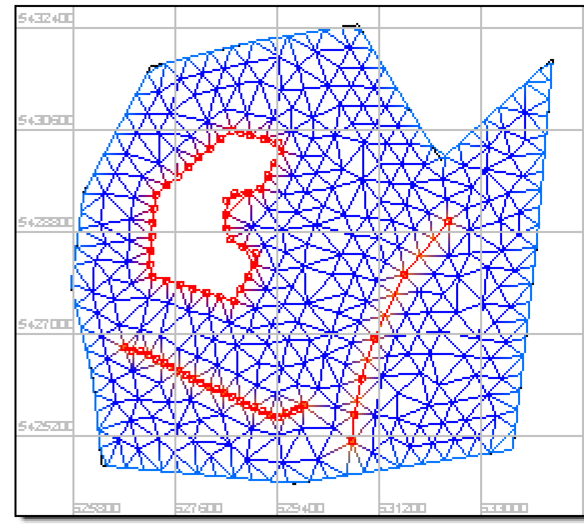
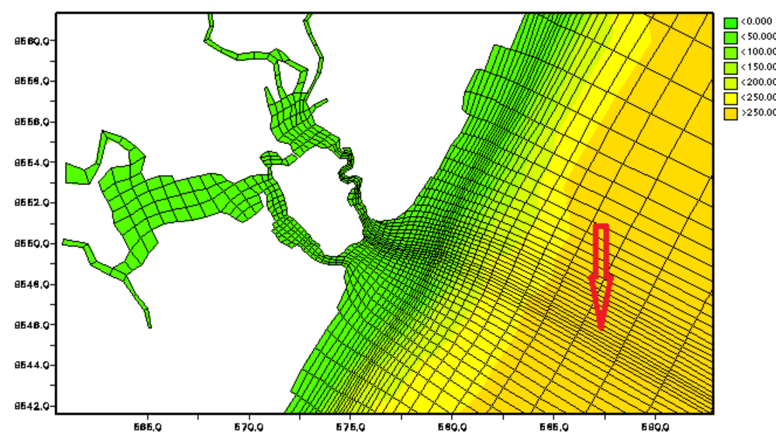
Unstructured grid vs Structured grids

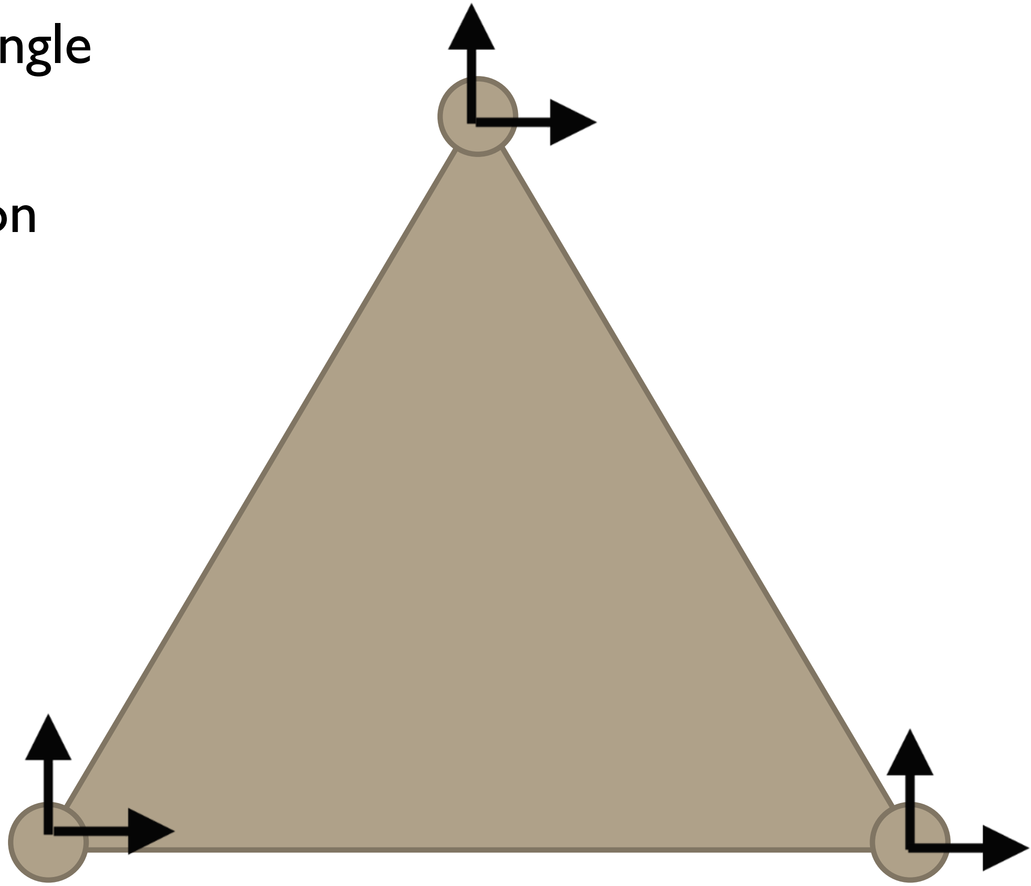
- Unstructured grid
  - List of points (1D!)
  - List of connection between those points
  - Can have any shape (triangle, square, hexagon)
  - More flexible
- Structured grid
  - Matrix (2D or 3D)
  - Only quadrilaterals (i.e. squares)
  - Less calculations pre time step
  - Many empty cells needed





Grid elements (2D)

- Data at the corners of the triangle
- Non-staggered
- U, V and H at the same location



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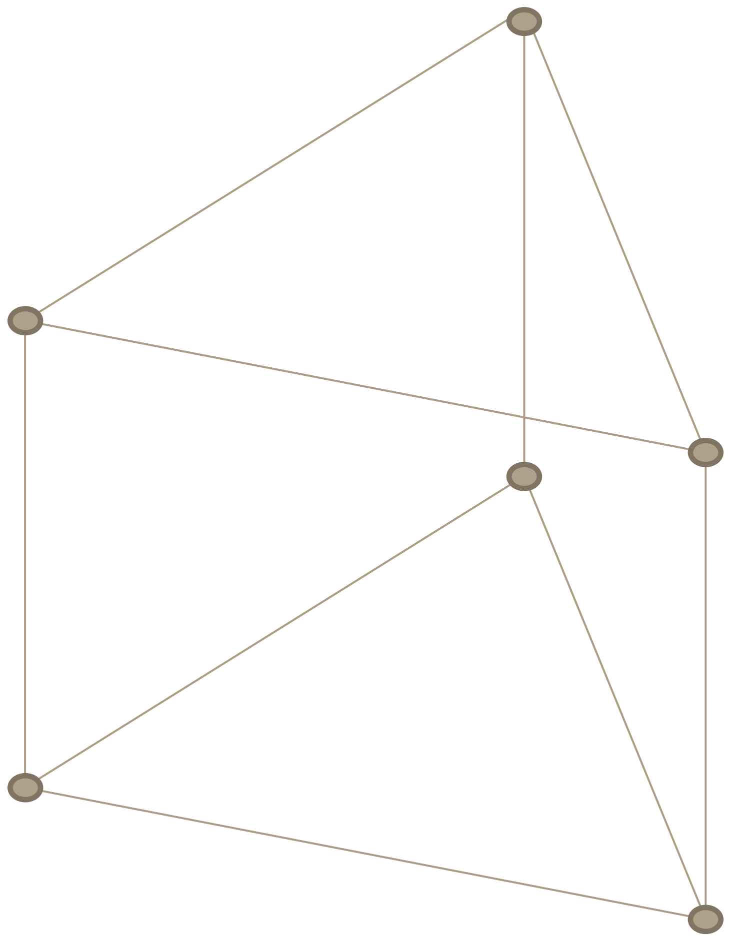
Grid elements (3D)

- Triangular Prism
- All data at the corners of the prism



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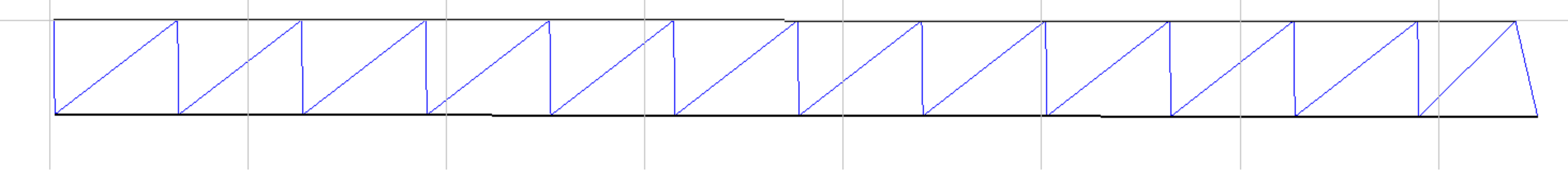
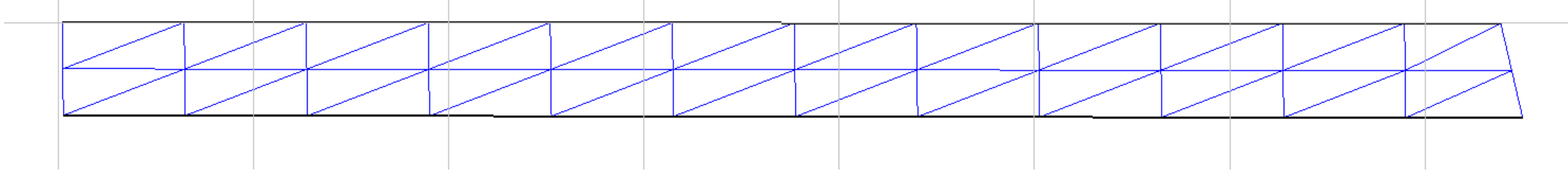
Overconstrained elements

- Elements needs at least one node that is not on the boundary
- Elements with all nodes on the boundary are called **overconstrained**
- No free flow is possible

Overconstrained mesh



Correct mesh



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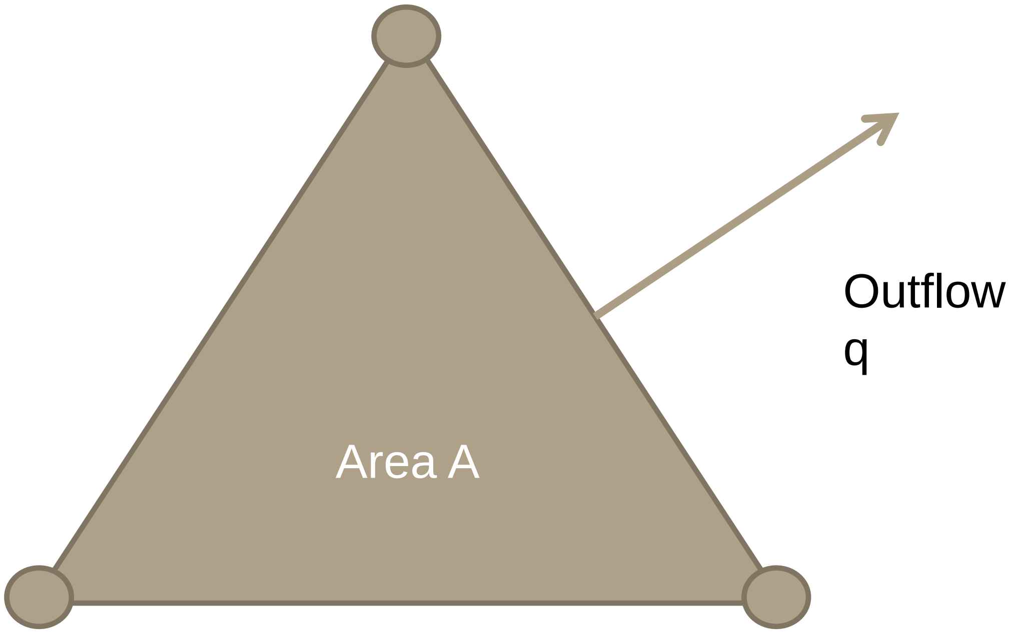
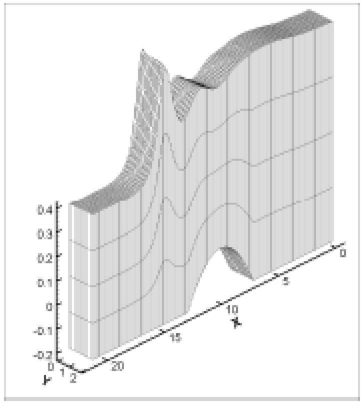
CFL number

- Structured mesh (square)
  - CFL = $\Delta t\ u / \Delta x$
- Unstructured mesh (triangle)
  - CFL = $\Delta t\ q / A$

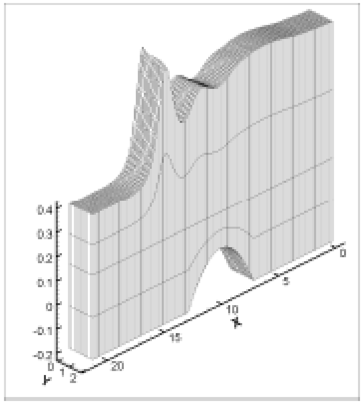


Grid 3D Types of vertical layering

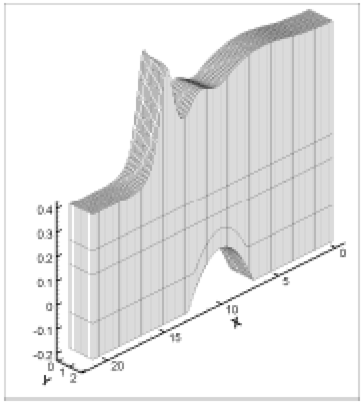
- Sigma coordinates
- Double sigma coordinates (fixed horizontal level)
- Combined sigma/z-coordinates (horizontal levels)



(a) 1 : sigma 2 : zstar



(b) 3 : fixed horizontal level



(c) 4 : horizontal levels

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Double sigma coordinates

- A fixed plane is used to separate two areas
- Sigma coordinates are used
  - Below the plane
  - Above the plane
- Useful in case you high resolution near the surface (e.g. density currents)

TELEMAC MODEL INPUT

TELEMAC peculiarities

- TELEMAC 2D and TELEMAC 3D are separate packages
  - Parameter file is not compatible!
  - Functionalities differ
  - Grid, and boundary conditions are compatible
  - Different variables in output file.
- Vertical coordinate system
  - Provide bed elevations rather than depth **(usually negative values**)
- The reference time is the **start of the simulation**
  - Make different boundary conditions with a different start time

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What is needed for a model

- Parameters, model settings:
  - **Cas file (.cas)**
- Grid, bathymetry and bottom roughness:
  - **Selafin file (.slf)**
- Definition of the type of boundary conditions:
  - **Boundary conditions file (.cli)**
- Time varying boundary conditions:
  - **Liquid boundary file (.txt)**
  - Binary boundary condition file(.slf)
  - Tidal files (OSU/TPXO)
- Initial conditions/restart file:
  - **Selafin file (.slf)**
- Everything else
  - fortran files (.f)

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Cas file

- Steering file (ascii text)
- Must be given as input to executable
- Can be in two languages
  - English
  - French
- Typically in the form of:
  - `parameter = value`
- Parameters are found in the **reference manual**
- Comments are possible `/ This is comment /`
- Multiple values separated by a `;`
- Maximum 72 characters on a line
- Ends with `&fin`

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Cas file example

```
/---------------------------------------------------------------------/
/   TELEMAC-3D  -  11401 HAVENUITBREIDING ZEEBRUGGE                   /
/                        01: PRESENT CONDITION                        /
/                        WRITTEN BY: ABR                         /
/                        DATE: 23-05-2013
/---------------------------------------------------------------------/
/
/---------------------------------------------
/  COMPUTER INFORMATIONS
/---------------------------------------------
/
GEOMETRY FILE                     = Grid_I4.slf
FORTRAN FILE                      = fortran_telemac3d.f
LIQUID BOUNDARIES FILE            = ZeebruggeDischarge2009Apr17.txt
BOUNDARY CONDITIONS FILE          = Grid_I4.cli
2D RESULT FILE                    = results2D.slf
3D RESULT FILE                    = results3D.slf
FORMATTED DATA FILE 1             = OBC2009Apr17.txt  / for boundary conditions;
FORMATTED RESULTS FILE            = HD100TimeSeries.txt
PARALLEL PROCESSORS               = 16

/---------------------------------------------
/ RESTART FILE
/---------------------------------------------

/COMPUTATION CONTINUED            = YES
/PREVIOUS COMPUTATION FILE        = Previous_salinity.slf
/INITIAL TIME SET TO ZERO          = YES


/
/---------------------------------------------
/  GENERAL INFORMATIONS - OUTPUTS
/---------------------------------------------
/
TITLE                                  = 'Zeebrugge Alternative I4'
VARIABLES FOR 2D GRAPHIC PRINTOUTS        = 'U,V,H,S,B,W,US'
VARIABLES FOR 3D GRAPHIC PRINTOUTS        = 'Z,U,V,W,TA1,NUX,NUY,NUZ'
```

Dictionary file

- All commands that you can use are defined in the .dico file
  - Sometimes useful as reference (similar as refence manual)
  - Should not be edited
  - In source code (e.g. source/telemac2d/telemac2d.dico)

```
NOM = 'STOCKAGE DES MATRICES'
NOM1 = 'MATRIX STORAGE'
TYPE = ENTIER
INDEX = 40
MNEMO = 'OPTASS'
TAILLE = 0
DEFAUT = 3
DEFAUT1 = 3
CHOIX = '1="EBE classique"';
'3="Stockage par segments"'
CHOIX1 = '1="classical EBE"';
'3="Edge-based storage"'
RUBRIQUE = 'PARAMETRES NUMERIQUES';'GENERAL'
RUBRIQUE1 = 'NUMERICAL PARAMETERS';'GENERAL'
NIVEAU = 1
AIDE = '1 : EBE classique  3 : Stockage par segments'
AIDE1 = '1 : classical EBE  3 : Edge-based storage'
```

Selafin file

- A Selafin file is a binary file that contains the grid
- Additional data that can be provided
  - bathymetry
  - spatially varying bed friction coefficient
- Made using **BlueKenoo**
- Model output has the same format!
- Other files that can be Selafin files:
  - Restart files (initial conditions)
  - Meteorology files (space and time varying wind)

Boundary condition file (.cli file)

- ASCII text file with information on the boundaries
- Made by **BlueKenue**
- Purpose is to specify the boundary condition type:
  - discharge
  - velocity
  - water level
  - closed
- Can be used to set constant values (in time) for values of boundaries

IMDC

Example .cli file

type of obc; values; type of tracer obc; values; nr of node; nr of boundary; text

```
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43939    2967  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43921    2968  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43902    2969  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43883    2970  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43877    2971  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43881    2972  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43892    2973  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43919    2974  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43951    2975  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    43977    2976  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    44014    2977  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    44038    2978  #
2 2 2  0.000 0.000 0.000 0.000  2  0.000 0.000 0.000    44057    2979  #
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    44073    2980  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    44024    2981  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    43907    2982  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    43775    2983  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    43554    2984  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    43282    2985  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    42987    2986  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    42661    2987  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    42322    2988  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    41985    2989  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    41638    2990  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    41437    2991  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    41172    2992  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    40379    2993  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    38657    2994  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    36802    2995  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    35054    2996  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    33298    2997  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    31400    2998  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    29405    2999  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    24321    3000  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    17910    3001  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    15323    3002  # seaBoundary
5 6 6  0.000 0.000 0.000 0.000  5  0.000 0.000 0.000    11575    3003  # seaBoundary
```

IMDC

Liquid boundary file

- ascii text file
- Specify time varying boundary conditions (per boundary segment; max 100 segments)
- Format:
  1. Header Variable(number of boundary segment)
     - Possible values(T: time; Q: discharge ; SL: water level; U, V: velocity; TR: tracer)
  2. Unit
  3. Data
- **Data are ignored if the header is wrong**
- Comments are possible: #
- Similar format for other time series input (wind)
- Also set keyword PRESCRIBED ELEVATION in .cas file

Liquid boundary file (example)

```
# Liquid boundaries file starting 17-Apr-2009
# Generated by Matlab
# 23-May-2013 15:36:36
T Q(7) Q(2) Q(1) Q(4) Q(3) Q(6) Q(5) TR(7) TR(2) TR(1) TR(4) TR(3) TR(6) TR(5)
S m3/s m3/s m3/s m3/s m3/s m3/s m3/s ppt ppt ppt ppt ppt ppt ppt
         0  20.450   61.400   15.321   11.350   46.300    7.750   33.600    0.000    0.000    0.000    0.000    0.000
      3600  20.646   60.792   16.060   11.696   46.908    7.796   34.150    0.000    0.000    0.000    0.000    0.000
      7200  20.842   60.183   15.855   12.042   47.517    7.842   34.700    0.000    0.000    0.000    0.000    0.000
     10800  21.038   59.575   14.749   12.387   48.125    7.888   35.250    0.000    0.000    0.000    0.000    0.000
     14400  21.233   58.967   14.493   12.733   48.733    7.933   35.800    0.000    0.000    0.000    0.000    0.000
     18000  21.429   58.358   14.469   13.079   49.342    7.979   36.350    0.000    0.000    0.000    0.000    0.000
     21600  21.625   57.750   15.063   13.425   49.950    8.025   36.900    0.000    0.000    0.000    0.000    0.000
     25200  21.821   57.142   15.648   13.771   50.558    8.071   37.450    0.000    0.000    0.000    0.000    0.000
     28800  22.017   56.533   15.465   14.117   51.167    8.117   38.000    0.000    0.000    0.000    0.000    0.000
     32400  22.212   55.925   15.125   14.463   51.775    8.163   38.550    0.000    0.000    0.000    0.000    0.000
     36000  22.408   55.317   15.195   14.808   52.383    8.208   39.100    0.000    0.000    0.000    0.000    0.000
     39600  22.604   54.708   15.418   15.154   52.992    8.254   39.650    0.000    0.000    0.000    0.000    0.000
     43200  22.800   54.100   17.167   15.500   53.600    8.300   40.200    0.000    0.000    0.000    0.000    0.000
     46800  23.008   55.133   22.097   15.388   54.162    8.300   40.433    0.000    0.000    0.000    0.000    0.000
     50400  23.217   56.167   15.998   15.275   54.725    8.300   40.667    0.000    0.000    0.000    0.000    0.000
     54000  23.425   57.200   15.033   15.163   55.287    8.300   40.900    0.000    0.000    0.000    0.000    0.000
     57600  23.633   58.233   15.651   15.050   55.850    8.300   41.133    0.000    0.000    0.000    0.000    0.000
     61200  23.842   59.267   16.638   14.937   56.413    8.300   41.367    0.000    0.000    0.000    0.000    0.000
     64800  24.050   60.300   16.068   14.825   56.975    8.300   41.600    0.000    0.000    0.000    0.000    0.000
     68400  24.258   61.333   15.367   14.713   57.537    8.300   41.833    0.000    0.000    0.000    0.000    0.000
     72000  24.467   62.367   16.001   14.600   58.100    8.300   42.067    0.000    0.000    0.000    0.000    0.000
```


IMDC

Fortran file

- You can replace any source code file in TELEMAC with your own modifications
- It uses fixed format Fortan
  - Strange errors occur if:
    - you use more than 72 characters on a line
    - you use the first 7 characters on a line
- Special input and output files can be used
- When do you use it?
  - Providing non-uniform vertical coordinates (sigma/ double sigma)
  - For advanced input (boundary conditions)
  - For advanced/custom output
  - Debugging strange errors/crashes
  - New functionalities (e.g. porcupine fields)

IMDC

What happens when running a model

- A python program takes care of the run
  - Files are copied to working directory
  - Fortran files are compiled
  - The model is divided in different domains (partel)
  - The model is run for each subdomain (mpi fortran)
  - The output files are put together (gretel)
  - The output files are copied back from the working directory
  - The working directory is cleaned up

IMDC

Example working directory

```
[abr@imdc-kickass ~]$ cd /mnt/data/projects/11401/Telemac/
[abr@imdc-kickass Telemac]$ ls
10hTelemacE1.e1267  10hTelemacE4.o1237  10hTelemacG1.e1258  10hTelemacG3.e1266    2dTelemacInicon.e1260  2dTelemacZee.o1493  HD60      HD64_salt  HD74  HD79  HD85  HD90  HD95  iniCon                 Telemac_phaseM2M4.e13
10hTelemacE1.o1267  10hTelemacE4.o1239  10hTelemacG1.o1258  10hTelemacG3.o1265    2dTelemacInicon.e1386  calibrationSalt     HD62      HD65       HD75  HD81  HD86  HD91  HD96  Telemac_OBCall.e1389   Telemac_phaseM2M4.o13
10hTelemacE4.e1237  10hTelemacE4.o1244  10hTelemacG2.e1263  10hTelemacG3.o1266    2dTelemacInicon.o1260  eddy                HD64      HD69       HD76  HD82  HD87  HD92  HD97  Telemac_OBCall.o1389   test
10hTelemacE4.e1239  10hTelemacE5.e1235  10hTelemacG2.o1263  10hTelemacHD79.e1259  2dTelemacInicon.o1386  HD100               HD64_new  HD72       HD77  HD83  HD88  HD93  HD98  Telemac_phaseall.e1388
10hTelemacE4.e1244  10hTelemacE5.o1235  10hTelemacG3.e1265  10hTelemacHD79.o1259  2dTelemacZee.e1493     HD101               HD64_sal  HD73       HD78  HD84  HD89  HD94  HD99  Telemac_phaseall.o1388
[abr@imdc-kickass Telemac]$ cd iniCon/
[abr@imdc-kickass iniCon]$ ls
2dTelemacInicon.e637  2dTelemacInicon.o908                     cas_HD64.txt_2013-06-18-10h11min32s  fortran_telemac3d_test    gridv10.slf    mpi_telemac.conf  ocf-parallel.lsf.script  ZeebruggeDischarge2009Apr17.txt
2dTelemacInicon.e908  cas_HD64.txt                             fortran_telemac3d                    fortran_telemac3d_test.f  lastStep2.slf  OBC2009Apr17.txt  Previous_salinity.slf    ZeebruggeDischarge2009Jan05.txt
2dTelemacInicon.o637  cas_HD64.txt_2013-06-06-14h53min32s  fortran_telemac3d.f                  gridv10.cli               lastStep.slf   OBC2009Jan05.txt  runModel
[abr@imdc-kickass iniCon]$ cd cas_HD64.txt_2013-06-18-10h11min32s/
[abr@imdc-kickass cas_HD64.txt_2013-06-18-10h11min32s]$ ls
cas_HD64.txt_2013-06-18-10h11min32s.sortie  PE00015-00006.LOG  T3DCLI00015-00001  T3DCLI00015-00014  T3DGEO00015-00006  T3DHYD00015-00003  T3DIMP             T3DPRE00015-00011  T3DRES00015-00007  T3DRFO00015-00004
CONFIG                                      PE00015-00007.LOG  T3DCLI00015-00002  T3DCLI00015-00015  T3DGEO00015-00007  T3DHYD00015-00004  T3DPRE             T3DPRE00015-00012  T3DRES00015-00008  T3DRFO00015-00005
out_fortran_telemac3d                       PE00015-00008.LOG  T3DCLI00015-00003  T3DDICO            T3DGEO00015-00008  T3DHYD00015-00005  T3DPRE00015-00000  T3DPRE00015-00013  T3DRES00015-00009  T3DRFO00015-00006
PARAL                                       PE00015-00009.LOG  T3DCLI00015-00004  T3DFO1             T3DGEO00015-00009  T3DHYD00015-00006  T3DPRE00015-00001  T3DPRE00015-00014  T3DRES00015-00010  T3DRFO00015-00007
partel_T3DGEO.log                           PE00015-00010.LOG  T3DCLI00015-00005  t3dfort.f          T3DGEO00015-00010  T3DHYD00015-00007  T3DPRE00015-00002  T3DPRE00015-00015  T3DRES00015-00011  T3DRFO00015-00008
partel_T3DGEO.par                           PE00015-00011.LOG  T3DCLI00015-00006  t3dfort.o          T3DGEO00015-00011  T3DHYD00015-00008  T3DPRE00015-00003  T3DRES             T3DRES00015-00012  T3DRFO00015-00009
partel_T3DPRE.log                           PE00015-00012.LOG  T3DCLI00015-00007  T3DGEO             T3DGEO00015-00012  T3DHYD00015-00009  T3DPRE00015-00004  T3DRES00015-00000  T3DRES00015-00013  T3DRFO00015-00010
partel_T3DPRE.par                           PE00015-00013.LOG  T3DCLI00015-00008  T3DGEO00015-00000  T3DGEO00015-00013  T3DHYD00015-00010  T3DPRE00015-00005  T3DRES00015-00001  T3DRES00015-00014  T3DRFO00015-00011
PE00015-00001.LOG                           PE00015-00014.LOG  T3DCLI00015-00009  T3DGEO00015-00001  T3DGEO00015-00014  T3DHYD00015-00011  T3DPRE00015-00006  T3DRES00015-00002  T3DRES00015-00015  T3DRFO00015-00012
PE00015-00002.LOG                           PE00015-00015.LOG  T3DCLI00015-00010  T3DGEO00015-00002  T3DGEO00015-00015  T3DHYD00015-00012  T3DPRE00015-00007  T3DRES00015-00003  T3DRFO00015-00000  T3DRFO00015-00013
PE00015-00003.LOG                           T3DCAS             T3DCLI00015-00011  T3DGEO00015-00003  T3DHYD00015-00000  T3DHYD00015-00013  T3DPRE00015-00008  T3DRES00015-00004  T3DRFO00015-00001  T3DRFO00015-00014
PE00015-00004.LOG                           T3DCLI             T3DCLI00015-00012  T3DGEO00015-00004  T3DHYD00015-00001  T3DHYD00015-00014  T3DPRE00015-00009  T3DRES00015-00005  T3DRFO00015-00002  T3DRFO00015-00015
PE00015-00005.LOG                           T3DCLI00015-00000  T3DCLI00015-00013  T3DGEO00015-00005  T3DHYD00015-00002  T3DHYD00015-00015  T3DPRE00015-00010  T3DRES00015-00006  T3DRFO00015-00003
[abr@imdc-kickass cas_HD64.txt_2013-06-18-10h11min32s]$
```

Logfiles (1 per processor)
OBC (1 per processor)
Grid (1 per processor)
2D output (1 per processor)
3D output (1 per processor)

IMDC

Lecture 01:3 TELEMAC installation

Alexander Breugem

IMDC

Objective of this lecture

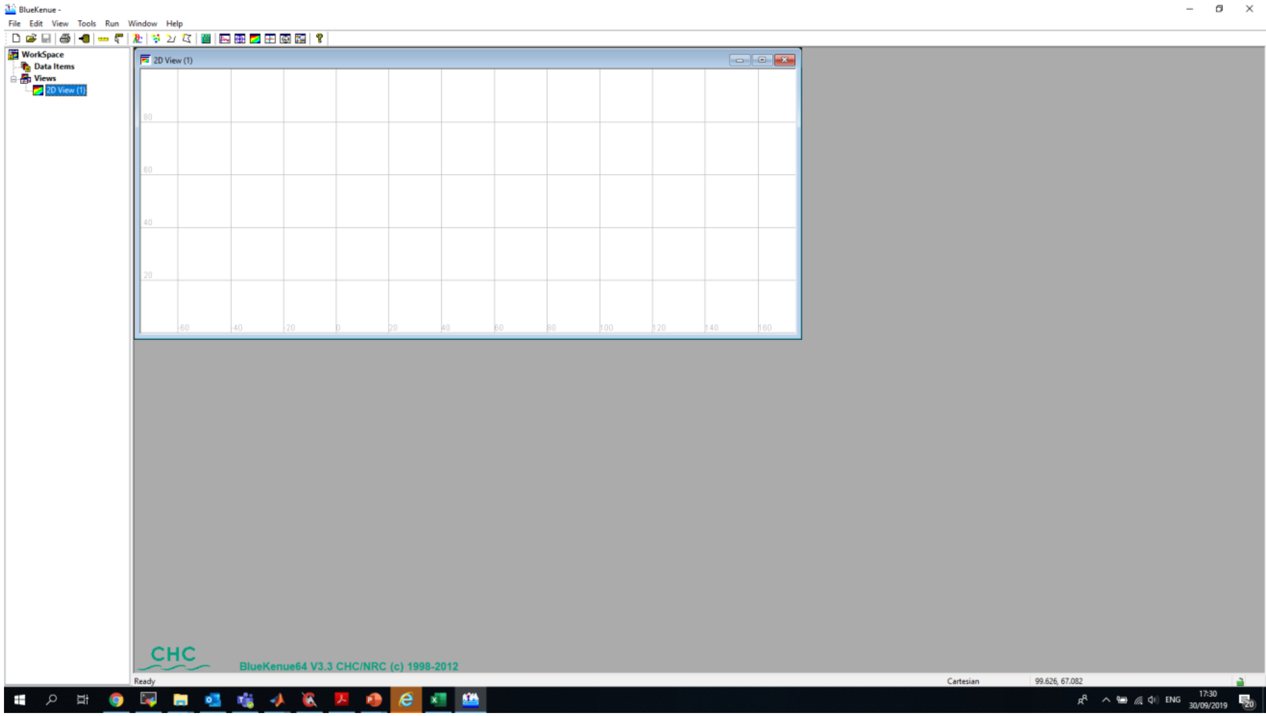
- Install necessary programs for Telemac
  - Python Anaconda
  - BlueKenue
  - MinGW compiler
  - MPI
- Install TELEMAC
- Control the correct working of TELEMAC

Install BlueKenue

- Run preinstallations\BlueKenue64Installer3.3.4.msi

Correct installation of BlueKenue

- Windows -> BlueKenue 64
- Should open BlueKenue



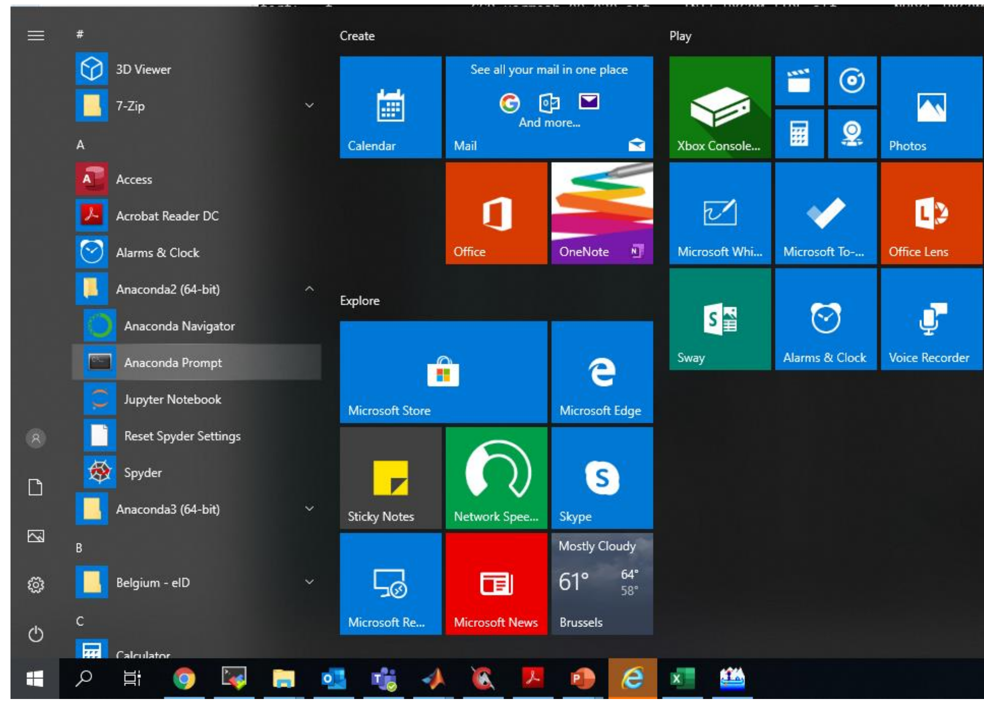
IMDC

Install python

- Run preinstallations\Anaconda2-5.3.1-Windows-x86_64.exe

Correct installation of Python Anaconda

- Start ->Anaconda2-> Anaconda prompt
- Type: `python -version`
- Should show Python 2.7



Anaconda Prompt

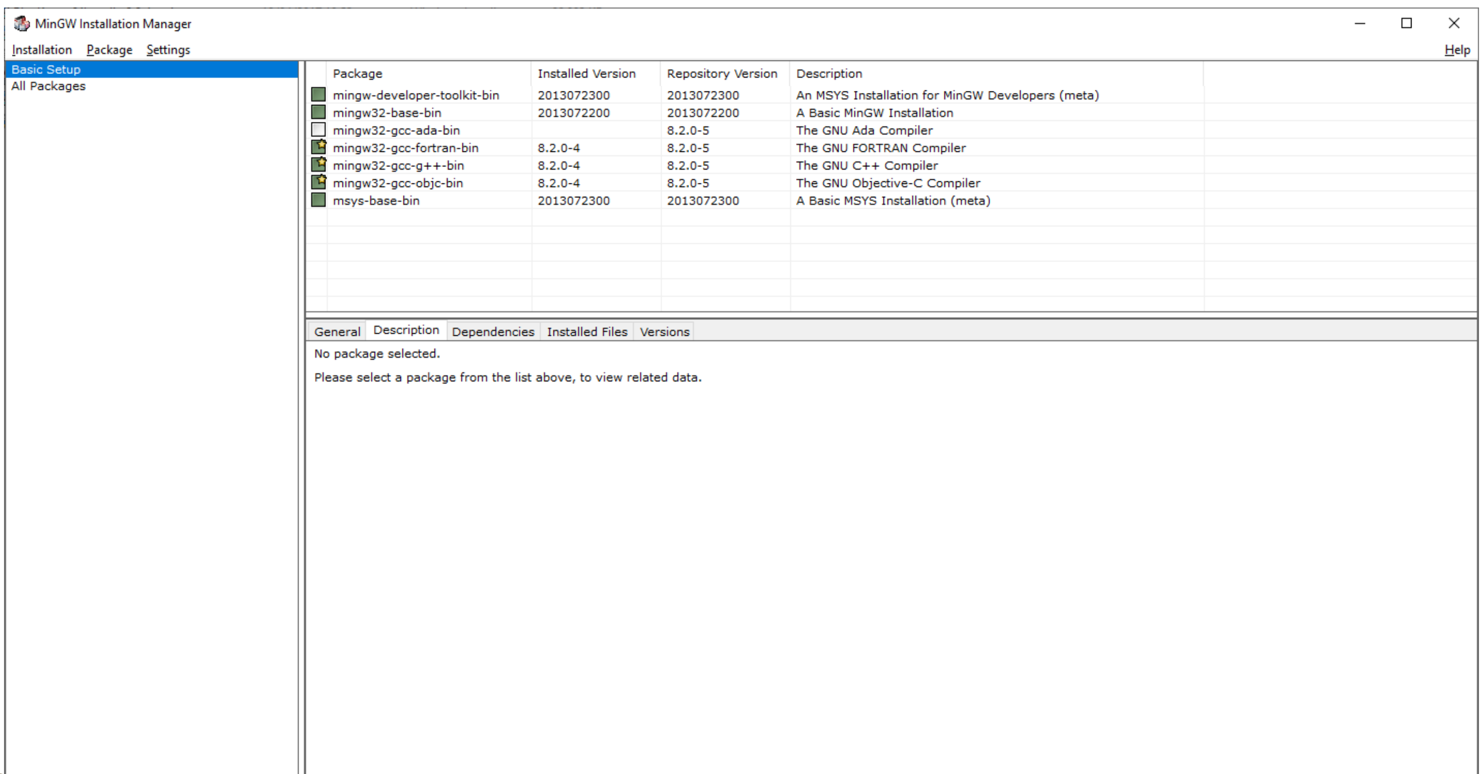
```
(base) C:\Users\abr>python --version
Python 2.7.15 :: Anaconda, Inc.

(base) C:\Users\abr>
```


IMDC

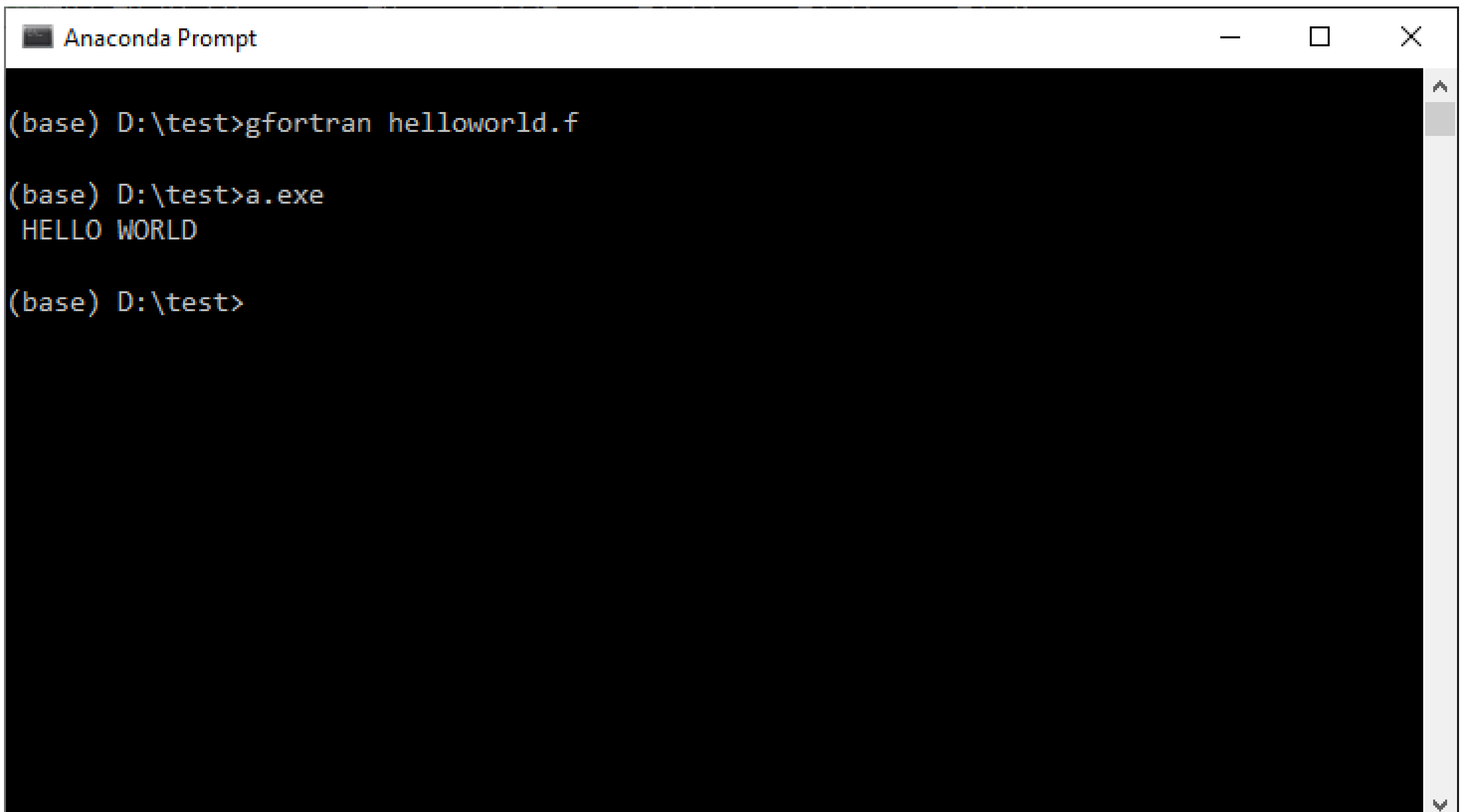
Install MinGW

- run preinstallations\mingw-get-setup.exe
- packages to install
  - gcc, gfortran, g++,msys



test MinGW

- Copy preinstallations\helloworld.f to a test directory (e.g. d:\test)
- See if it compiles and runs



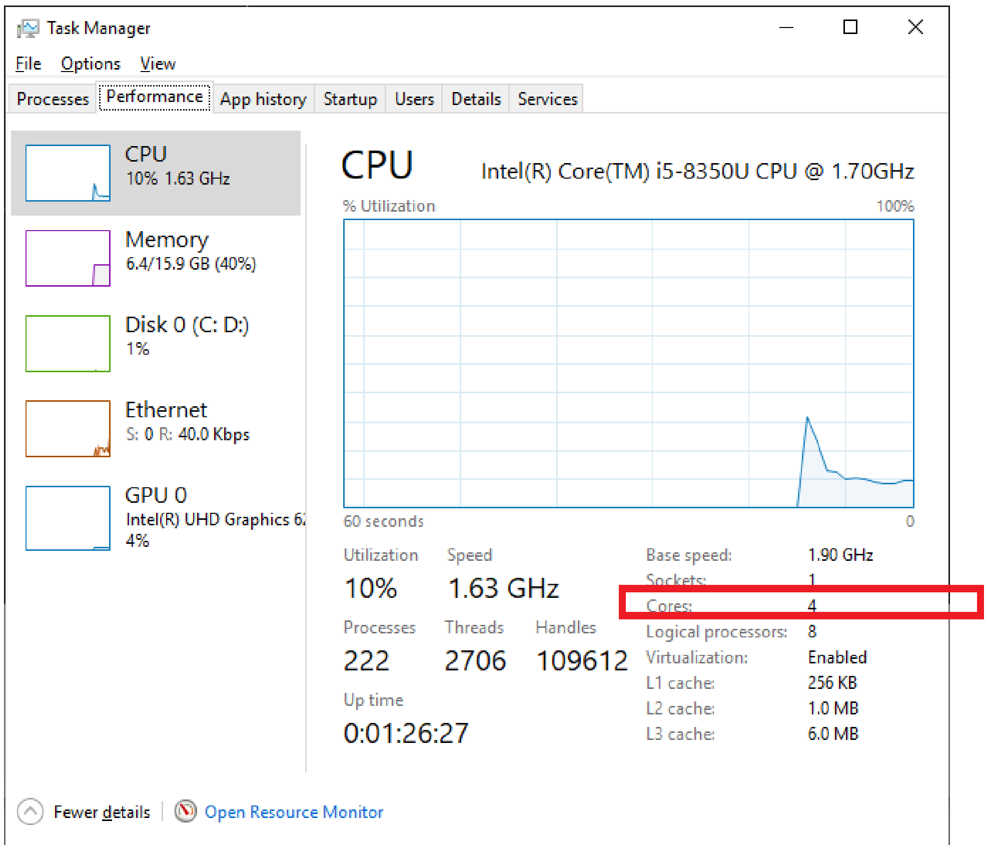
Install mpi and necessary libraries

- run preinstallations\msmpisetup.exe
- make directory c:\lib
- cp preinstallations\lib* to c:\lib

IMDC

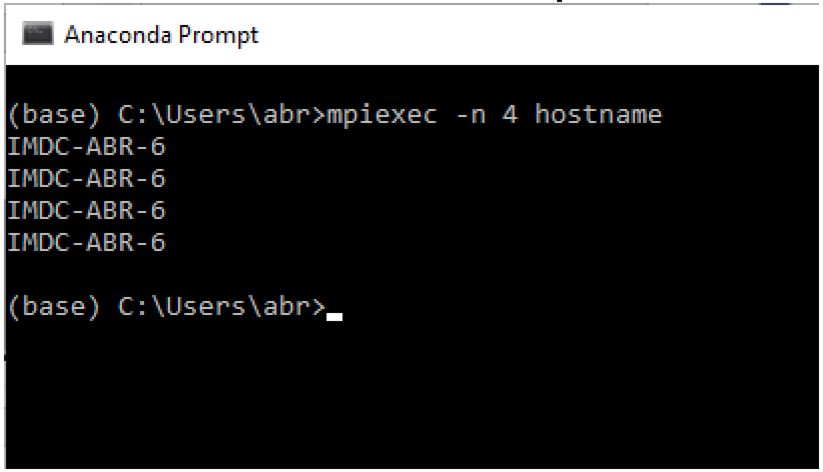
Determine number of processors

- Start-> taskmanager-> performance



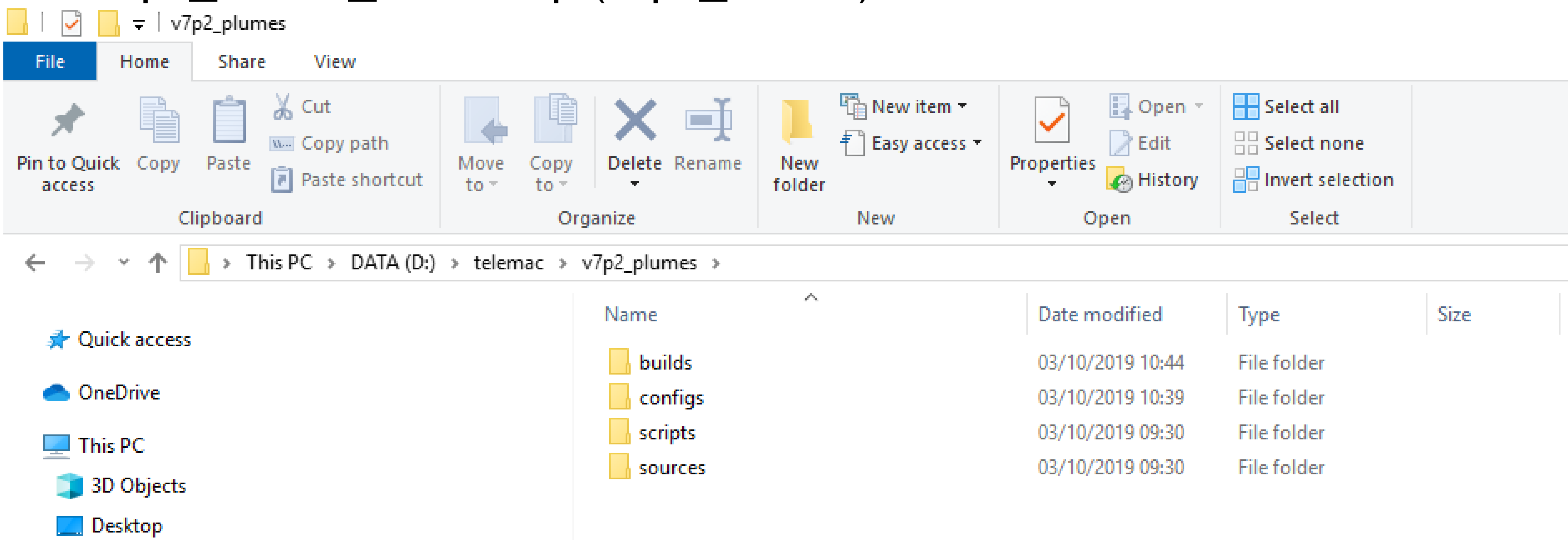
Correct installation of mpi

- `mpiexec -n 4 hostname`
- Should show 4 times the name of the computer



Installation of TELEMAC (1)

- Copy TELEMAC installation to local drive from v7p2_cookie_course.zip (v7p2_cookie)



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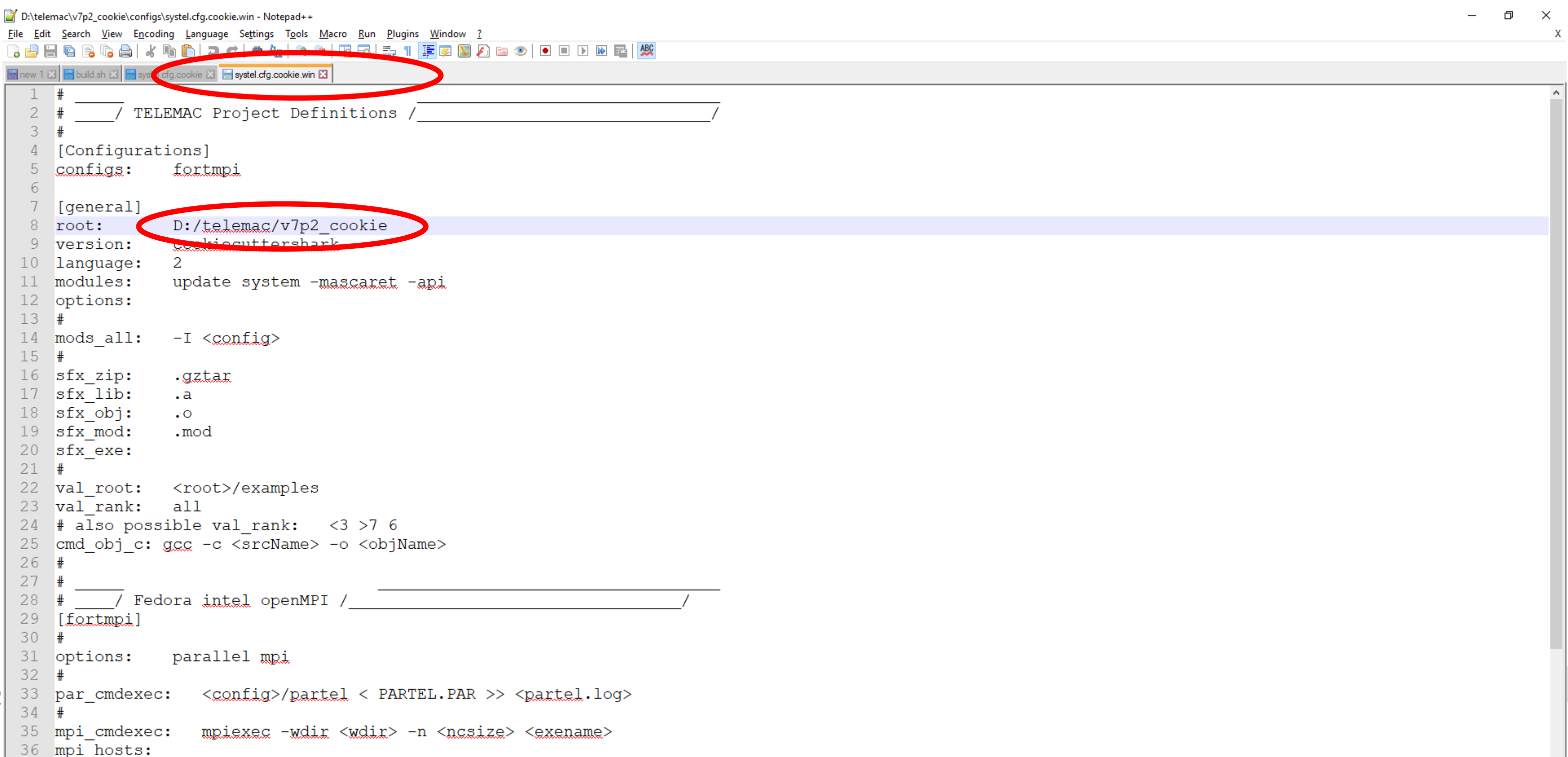
Installation of TELEMAC (2)

- Edit `configs\systel.cfg.cookie.win` to set the path.
- Use forward slashes!
- No slash at the end!

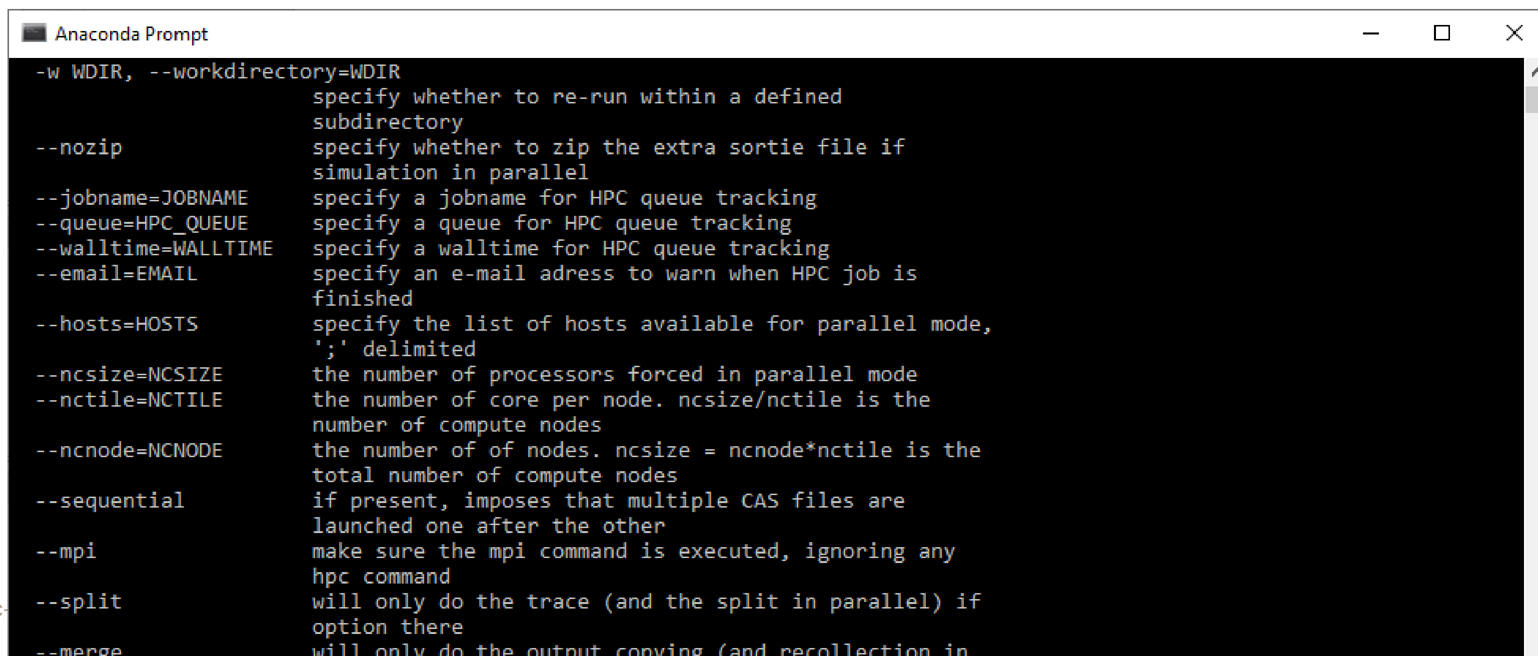



```
#  _____
# ____/ TELEMAC Project Definitions /________________________________/
#
[Configurations]
configs:     fortmpi

[general]
root:        D:/telemac/v7p2_cookie
version:     cookiecuttershark
language:    2
modules:     update system -mascaret -api
options:
#
mods_all:    -I <config>
#
sfx_zip:     .gztar
sfx_lib:     .a
sfx_obj:     .o
sfx_mod:     .mod
sfx_exe:
#
val_root:    <root>/examples
val_rank:    all
# also possible val_rank:   <3 >7 6
cmd_obj_c: gcc -c <srcName> -o <objName>
#
#  _____                            ___________________________________
# ____/ Fedora intel openMPI /__________________________________/
[fortmpi]
#
options:     parallel mpi
#
par_cmdexec:    <config>/partel < PARTEL.PAR >> <partel.log>
#
mpi_cmdexec:    mpiexec -wdir <wdir> -n <ncsize> <exename>
mpi_hosts:
```

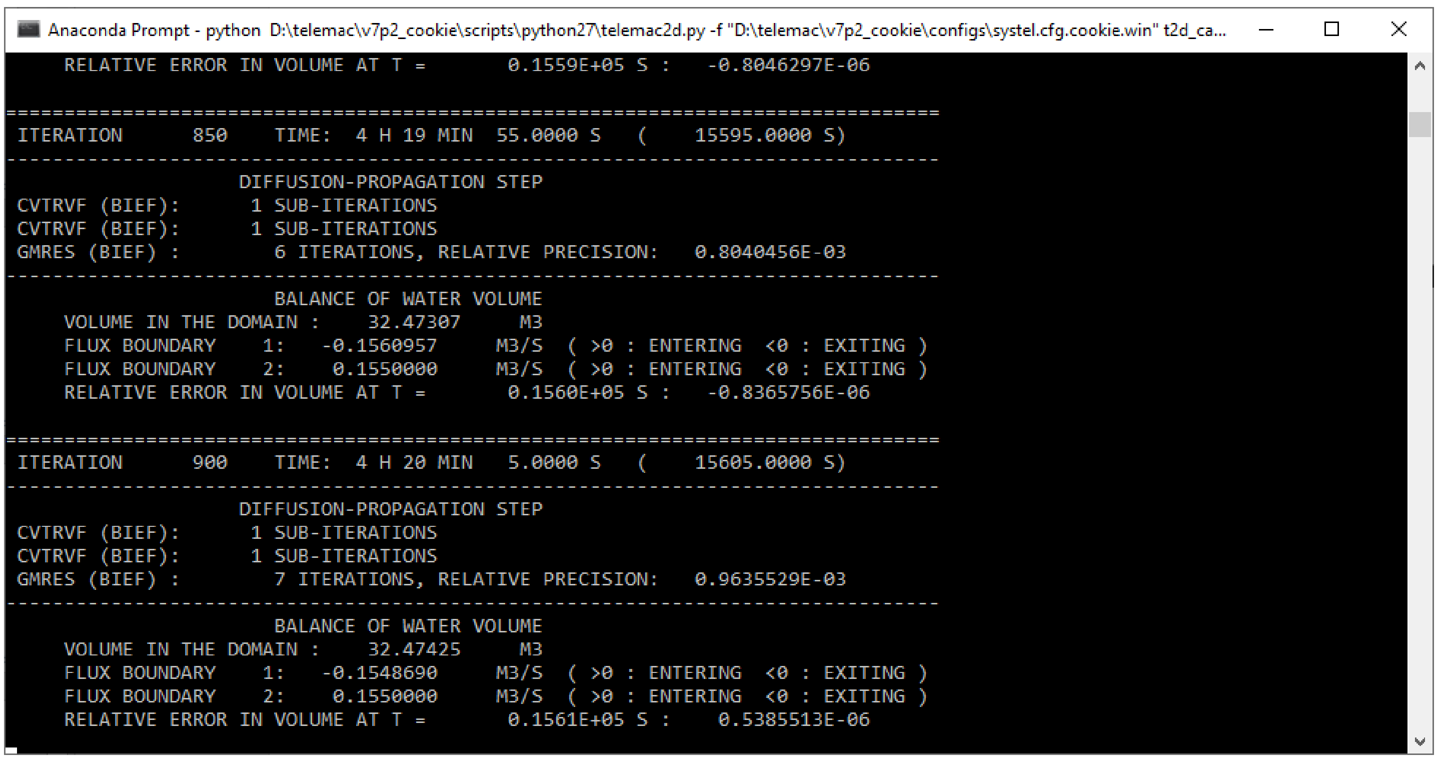
Test TELEMAC (I)

- Copy `examples\telemac2d\cavity` to a new directory (e.g. `c:\test\`
- **Restart Anaconda prompt**
- Type: `cd c:\telemac\v7p2_cookie\`
- Type: `loadCookie.bat`
- Type : `cd c:\test\cavity`
- Type : `telemac2d.bat -h`



Test TELEMAC (2)

- Type: telemac2d.bat t2d_cavity.cas
- Should run TELEMAC:



Congratulations. TELEMAC is installed.

Anaconda Prompt

```
 END OF TIME LOOP

 EXITING MPI

 CORRECT END OF RUN

 ELAPSE TIME :
                            30  SECONDS


~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

... merging separated result files

    +>  t2d_cavity.cas


~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

... handling result files

    +>  t2d_cavity.cas
        moving:  r2d_cavity.slf


My work is done


(base) d:\test\cavity>
```

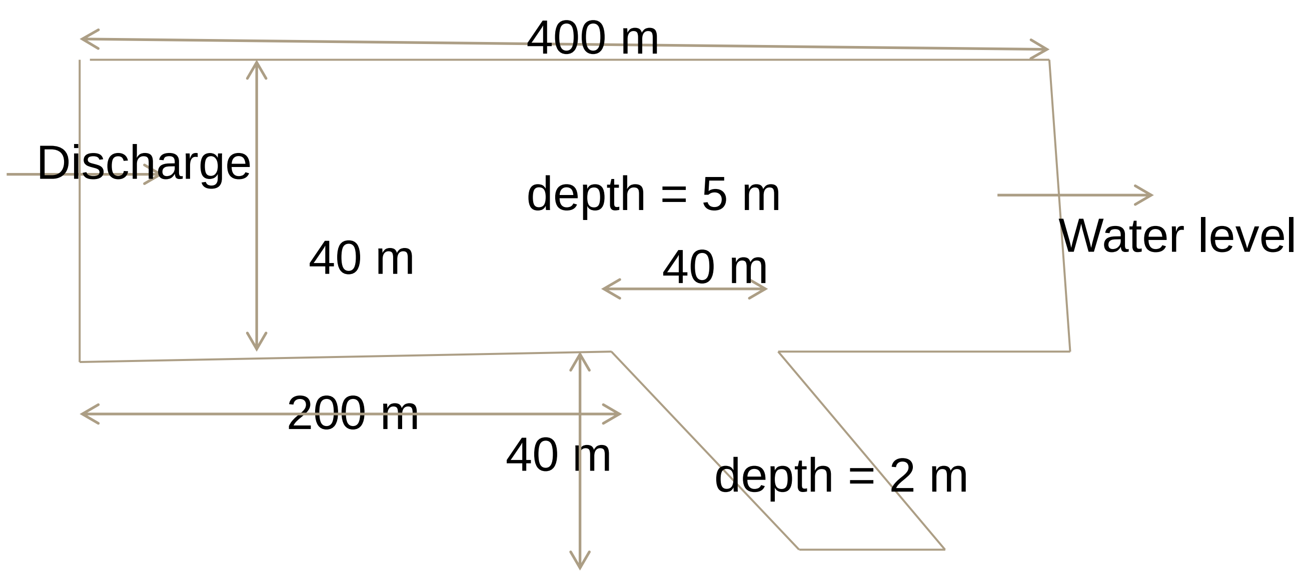
Lecture 1.4 Preprocessing and mesh generation in BlueKenue (1)

Alexander Breugem

IMDC

Objective

- Learn to make meshes with BlueKenue
- Lear how to determine boundary conditions
- Learn how to interpolate bathymetry
- Make your first model of a cavity flow



GENERAL

BlueKenoo general

- Almost everything is an ASCII file
- You will get a lot of files
- Work structured from the beginning! **Use clear names**
- Be careful with “save a copy”
- There is no “undo button”
- There is no “graphical editing”

Mesh generation general methodology

- All scenarios are done by making changes to the mesh
- Therefore: **you make a new mesh for every scenario!**
- However: mesh generation is fast

- Thus:
  - Save the settings for making the mesh (.t3m file). You need them again
  - Change the mesh only in areas where your scenario changes.

IMDC

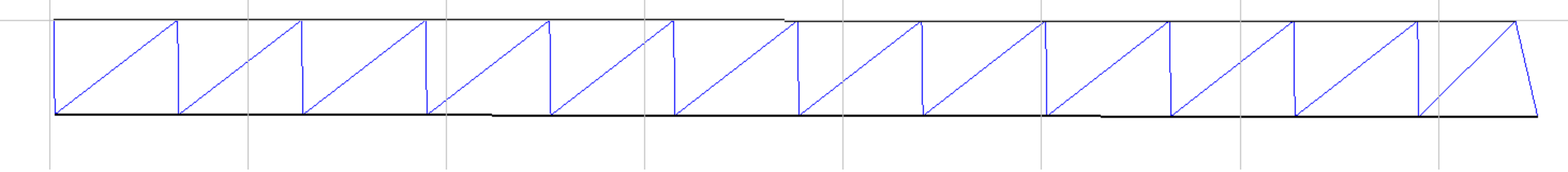
Mesh requirements(1)

- Specify the resolution based on the problem that you are studying. Always make the mesh **as course as possible**, otherwise the model is slow.
- Try to make triangles with angles of **60 degrees** (elongated in flow direction is ok)
- Check mesh quality (no sharp pointed elements, as little elements with angles > 90 deg as possible). Elements should look as equilateral as possible
- Make sure there are **no sudden changes in resolution**
- Delete/adjust **overconstrained** elements. No flow is possible through these elements.
-

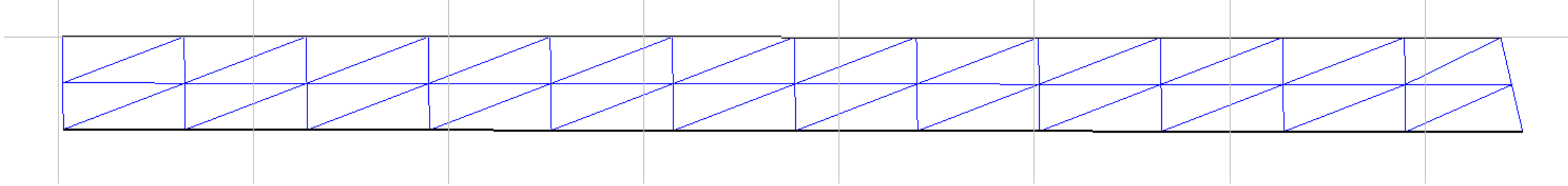
Overconstrained elements (reminder)

- Elements needs at least one node that is not on the boundary
- Elements with all nodes on the boundary are called **overconstrained**
- No free flow is possible

Overconstrained mesh



Correct mesh



IMDC

Mesh requirements(2)

- The grid must follow the bathymetry!
  - Otherwise you get bumps that lead to extra dissipation
- The maximum number of triangles in a node should be as low as possible (max 10)
- Specific for channels:
  - Triangles should be aligned in the flow direction
  - Maximum stretching 1:3

IMDC

Mesh resolution

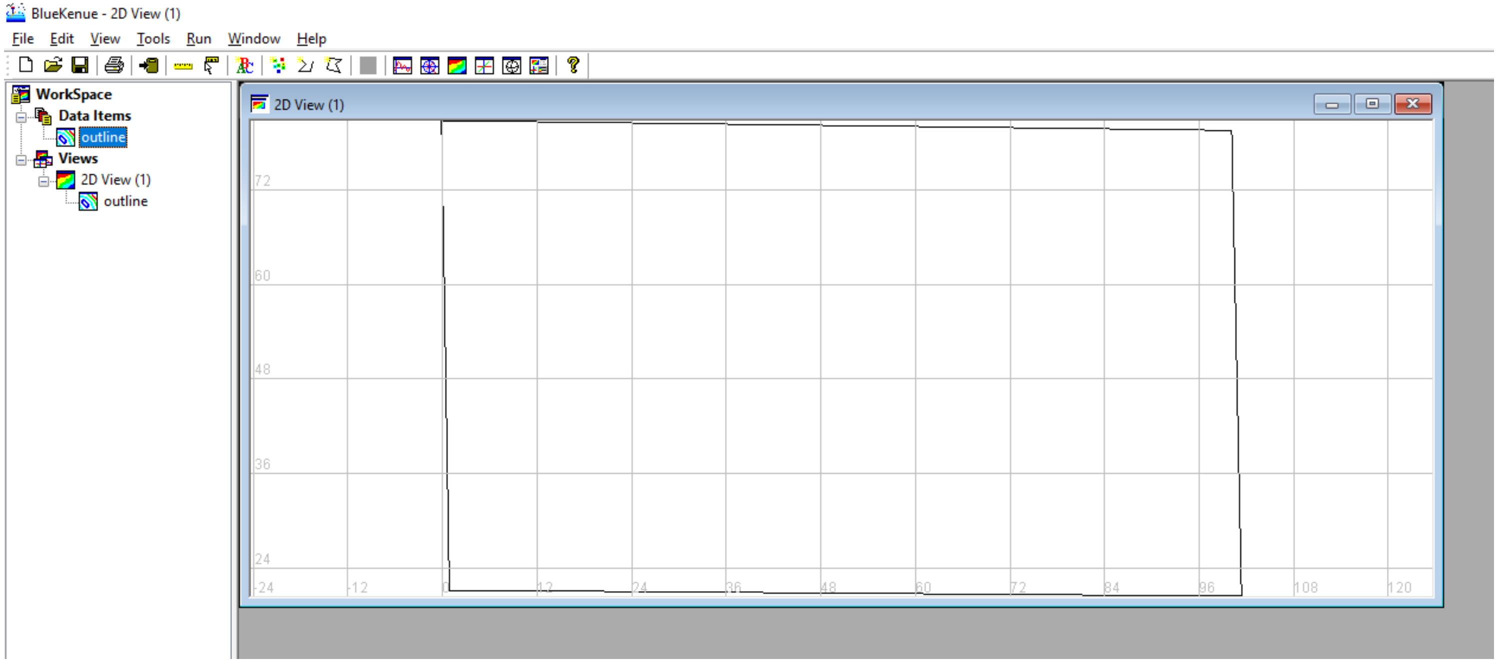
- Specific for mesh resolution:
  - When nesting use the same resolution at the boundary as used in the mother model
  - Use a sufficient number of points per wavelength. You need a finer resolution for a tsunami than for a tidal model.
  - Refine in the area of interest.
  - Take the bathymetry into account when refining. Use a higher resolution in areas with a steep gradient in the bathymetry. Use at least 10 points in an to simulate an eddy e.g. between groynes (more is better)
  - Use high resolution at location of **drying flooding (**Difference in bathymetry in an element should be less than the depth)

IMDC

BlueKenue; working with lines

BlueKenue: working with lines (1)

- Uses lines to make the mesh
  - Make a new closed line
  - **Give it a clear name!**
  - Save to disk (.i2s file)



BlueKenue: working with lines (2)

- Edit lines in a text editor.
- Format is very simple. Easy to import data in this way.

D:\test\izmir\outline.i2s - Notepad++

```
#########################################################################
:FileType i2s  ASCII  EnSim 1.0
# Canadian Hydraulics Centre/National Research Council (c) 1998-2012
# DataType                 2D Line Set
#
:Application               BlueKenue
:Version                   3.3.4
:WrittenBy                 IGG285
:CreationDate              Mon, Sep 30, 2019 06:44 PM
#
#------------------------------------------------------------------------
:Name  outline
#
:AttributeUnits 1 m
:EndHeader
5 0
-0.124688 80.798005
0.872818 21.197007
101.371571 20.448878
100.124688 79.551122
-0.124688 80.798005

```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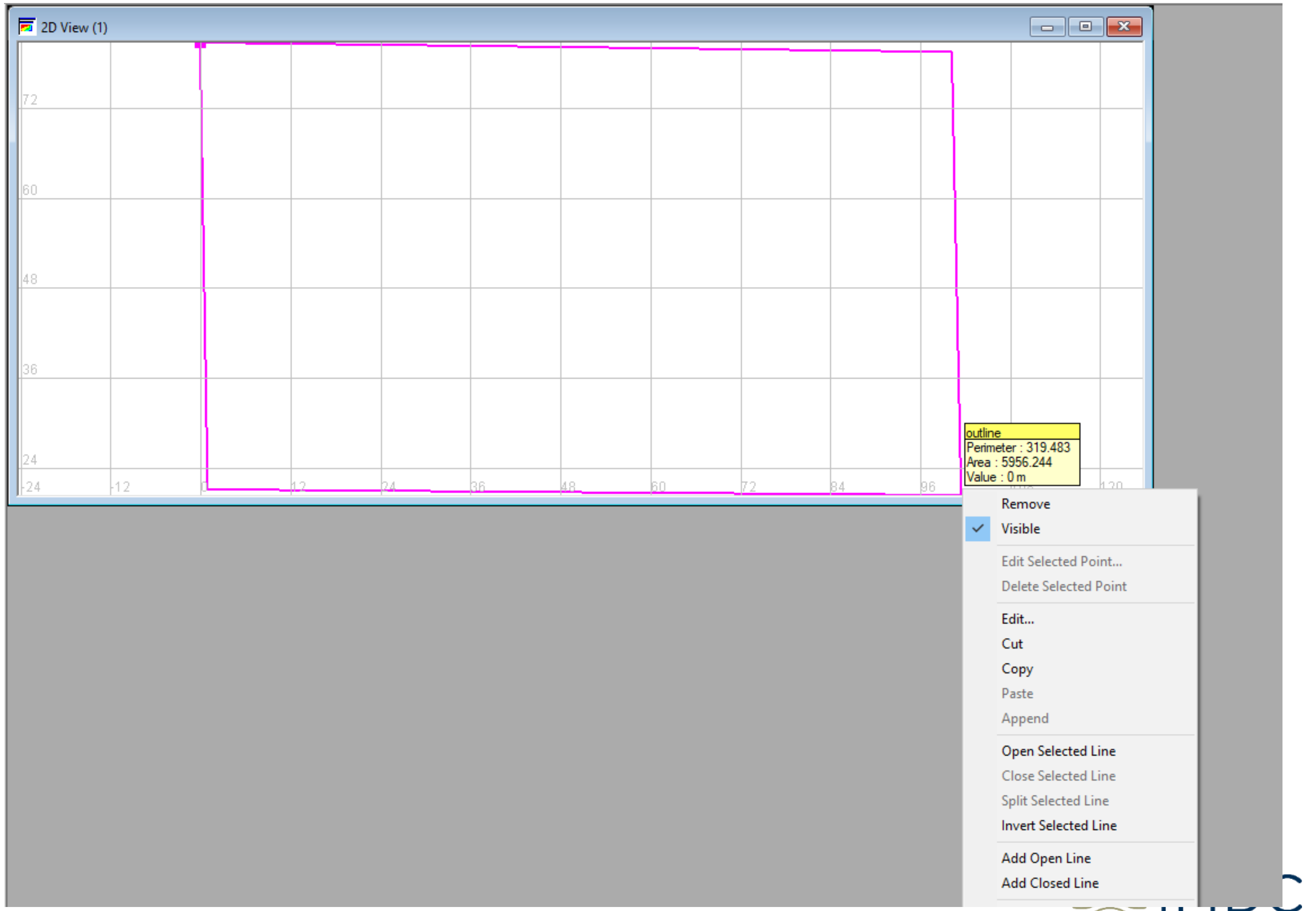
BlueKenue working with lines (3)

- More advanced options when working with lines (using right mouse button):
  - Split lines
  - Open/close
  - Edit points
  - Invert
  - Append
  - Resample
  - Delete points



BlueKenue working with lines (4): Splitting/editing lines

- Splitting/editing lines in frequently needed (changing scenario's)
- Steps:
  - right mouse -> open line
  - right mouse -> split line
  - right mouse -> cut line
  - add new line with dummy points
  - paste into new line
  - select + cut dummy points
  - save

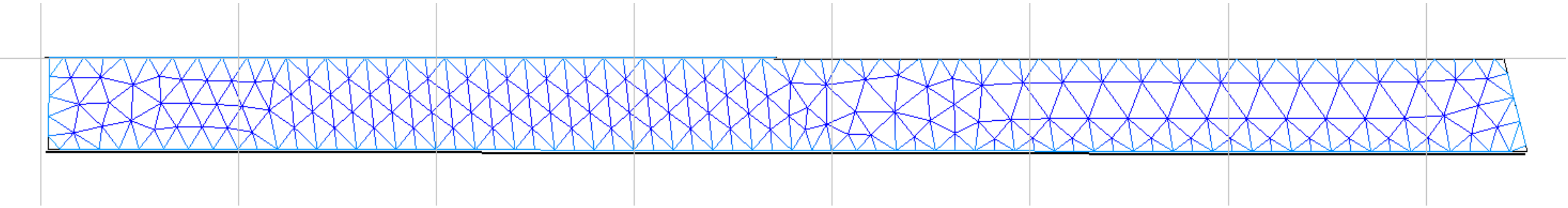
IMDC

BlueKenue: making meshes

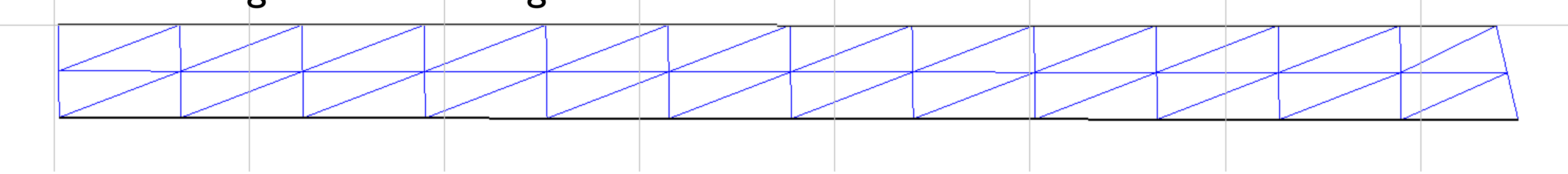
IMDC

Bluekenue: types of meshes

- Normal mesh (unstructured)
  - Made from closed polyline
  - Equilateral triangles



- Channel mesh ("structured")
  - Made from two open polylines
  - Triangles can be elongated



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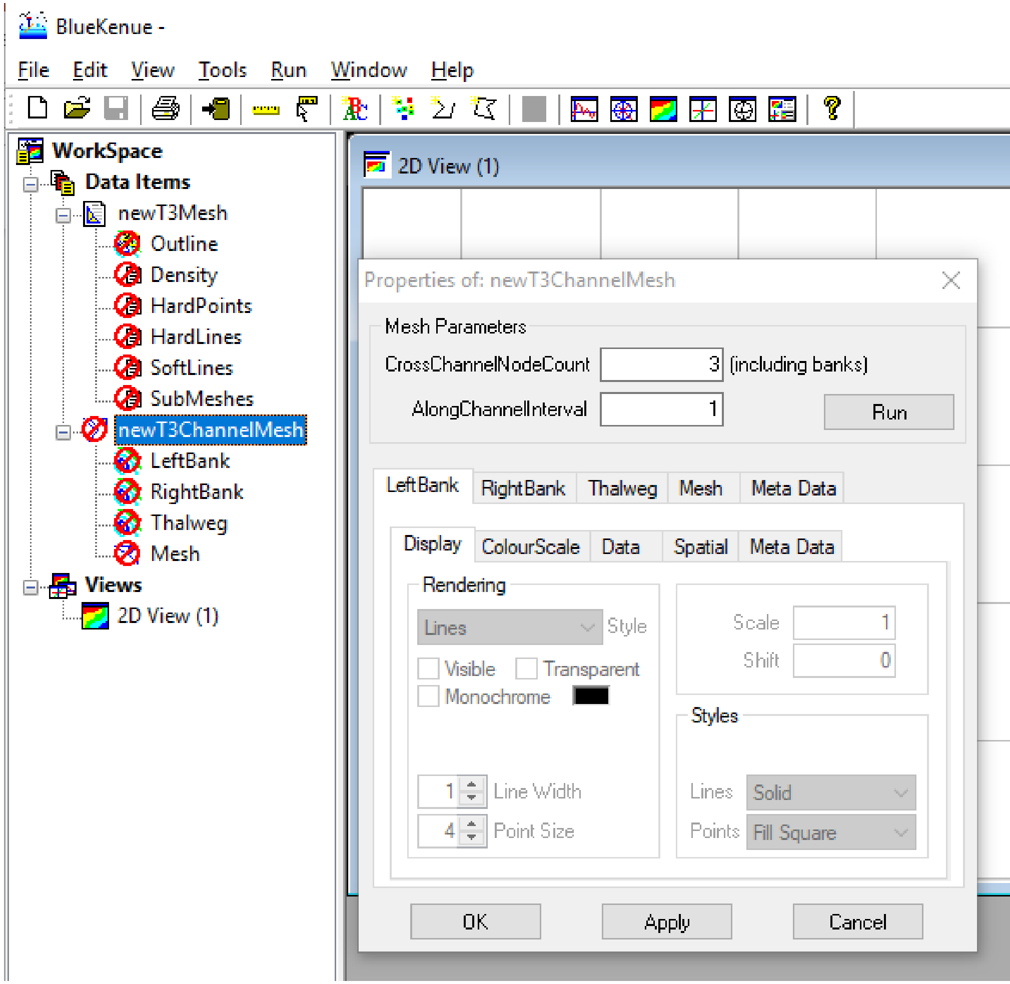
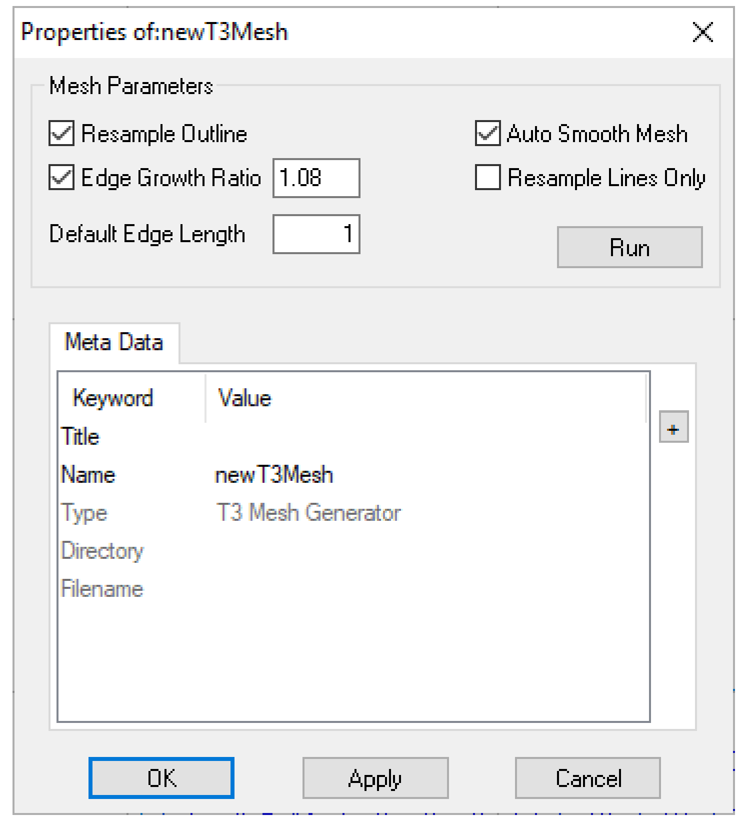
BlueKenue: make a channel mesh

- ->File-> New -> T3D channel Mesher
- drag lines to LeftBank and RightBank
- Optionally add Thalweg
- edit settings (resolution)
- ->Run
- Drag mesh to 2d view



BlueKenue: make an unstructured mesh

- ->File -> new-> T3D mesh generator
- Drag closed polyline to outline
- Additionally extra elements
- Set parameters (edge growth ratio = 1.08)
- Run
- Drag "New mesh" to 2D view



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Needed for unstructured mesh generation

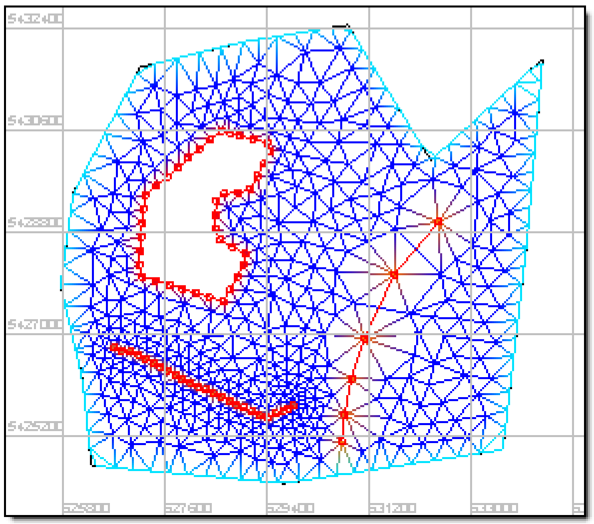
- Outline: a closed polyline in which the grid is made

- Optional:
  - Density: some file specifying the size of the triangles
  - Hard points/hard lines: a grid point is made at these locations
  - Soft lines: the grid points are put at this line, according to specified resolution
    - To make islands
    - To influence the shape of the grid (e.g. follow the bathymetry)
  - Extra grids (which are nested in the new grid)

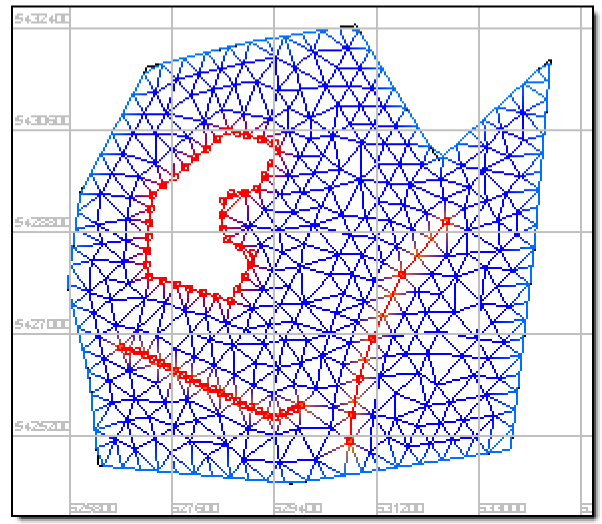
IMDC

Hard lines vs. soft lines

- In red, the input data is given



Hard line
(only resamples points are used)



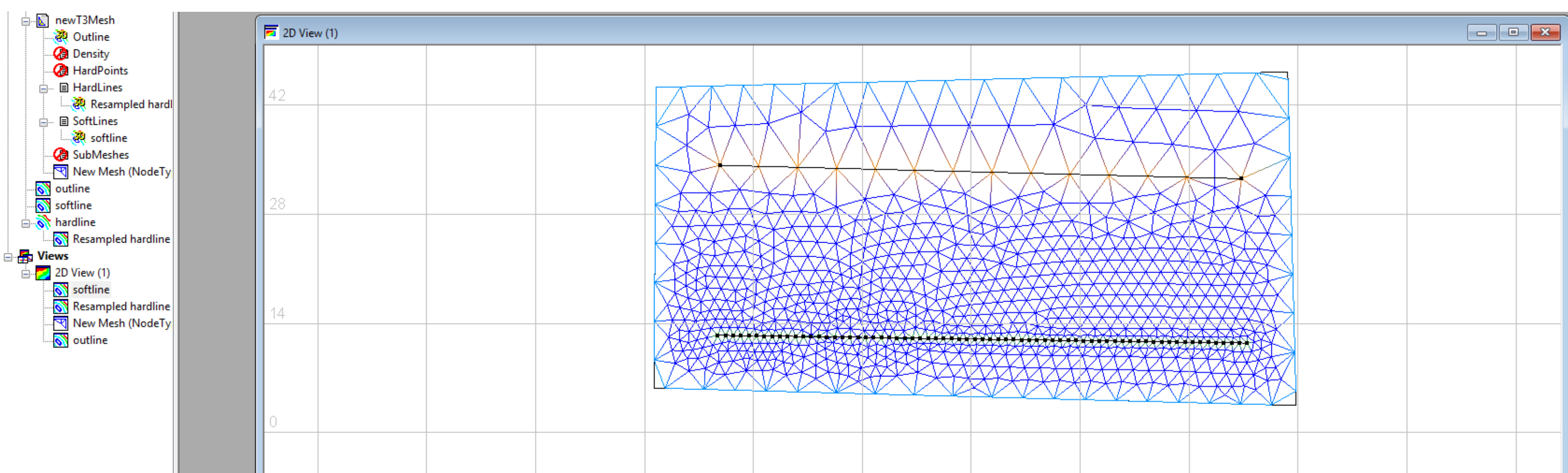
Soft line
(lines are first resampled)

BlueKenue: meshing algorithm

- Uses a dynamic moving front algorithm Delaunay triangulation
  - Resample outline and softlines
  - Add points from hard lines and submeshes
  - Add new points (based on density) around points with smallest density
  - Make unconstrained Delauney triangulation
  - Delete triangles outside outline or inside submeshes or islands
  - Merge submeshes
  - Smooth the mesh
- Triangulation often starts from points on the boundary!
- The way the outlines is resamples determines what the mesh looks like
- **Check the resampling of the outline!**

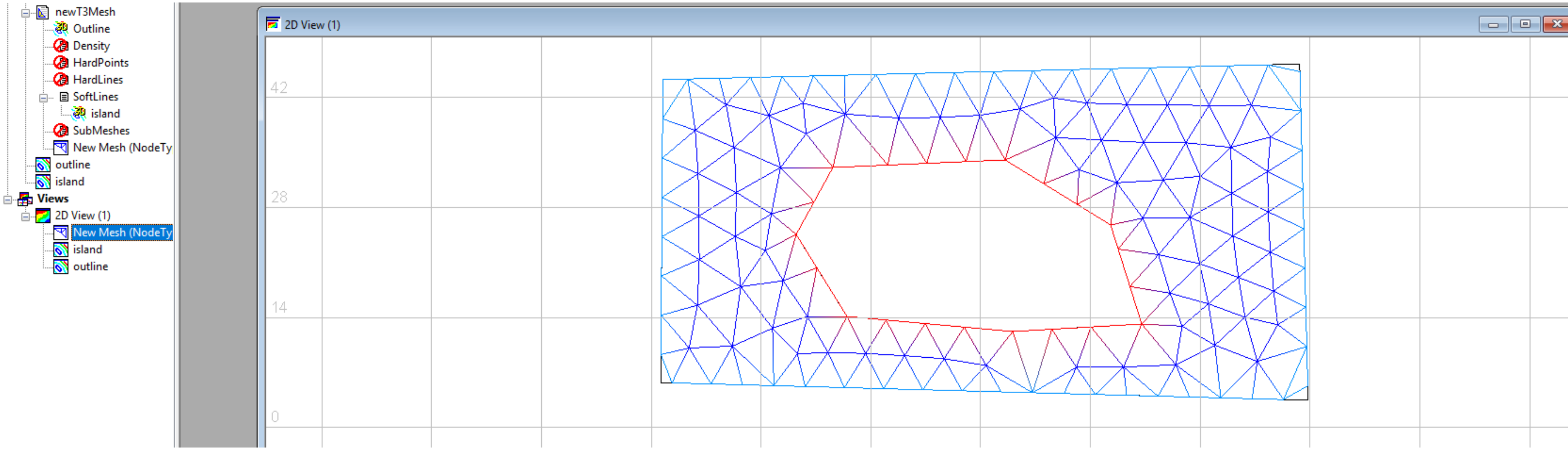
Blue Kenue: hard lines and soft lines to accentuate features

- Make a new **open** polyline
  - Option1 (Soft line);
    - Drag polyline to SoftLines
    - Run mesh generator
  - Option 2 (Hard line)
    - Resample polyline (using the required mesh resolution)
    - Drag polyline to HardLines
    - Run the mesh generator
  - Observe the differences



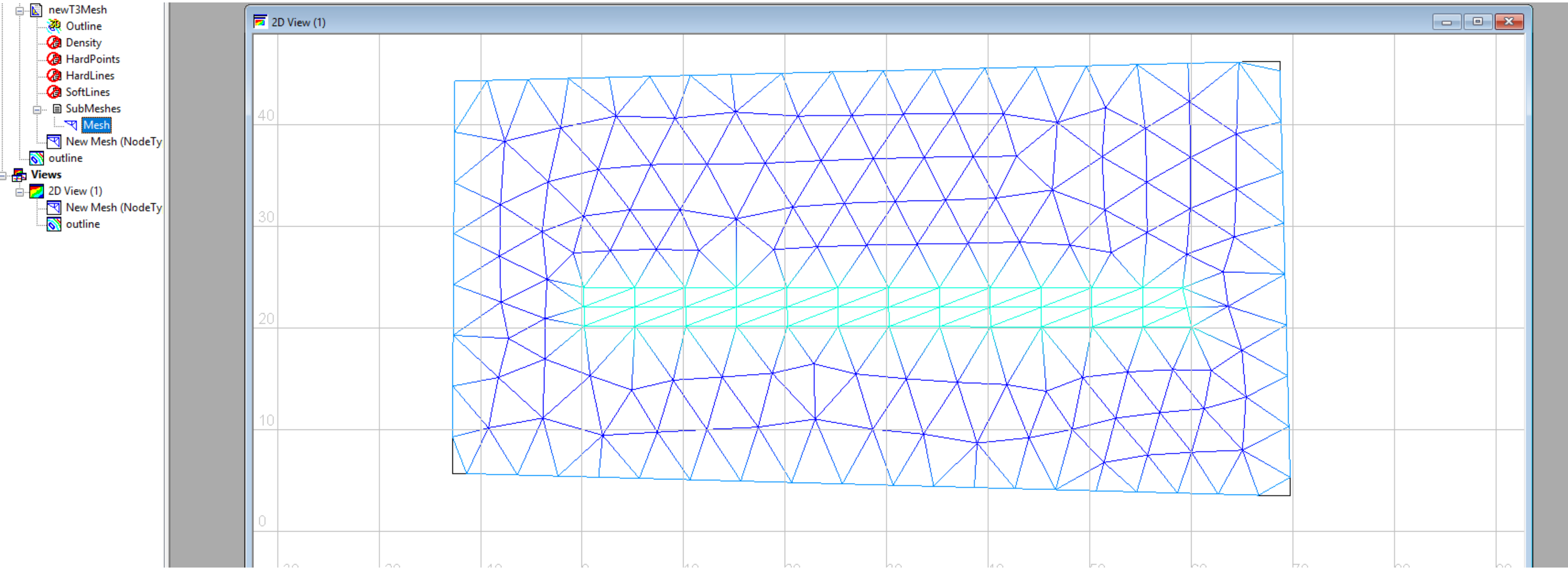
BlueKenue: adding islands

- Make a new **closed** polyline
- Option1 (Soft line);
  - Drag polyline to SoftLines
  - Run mesh generator
- Option 2 (Hard line)
  - resample polyline (using the required mesh resolution)
  - Drag polyline to HardLines
  - Run the mesh generator



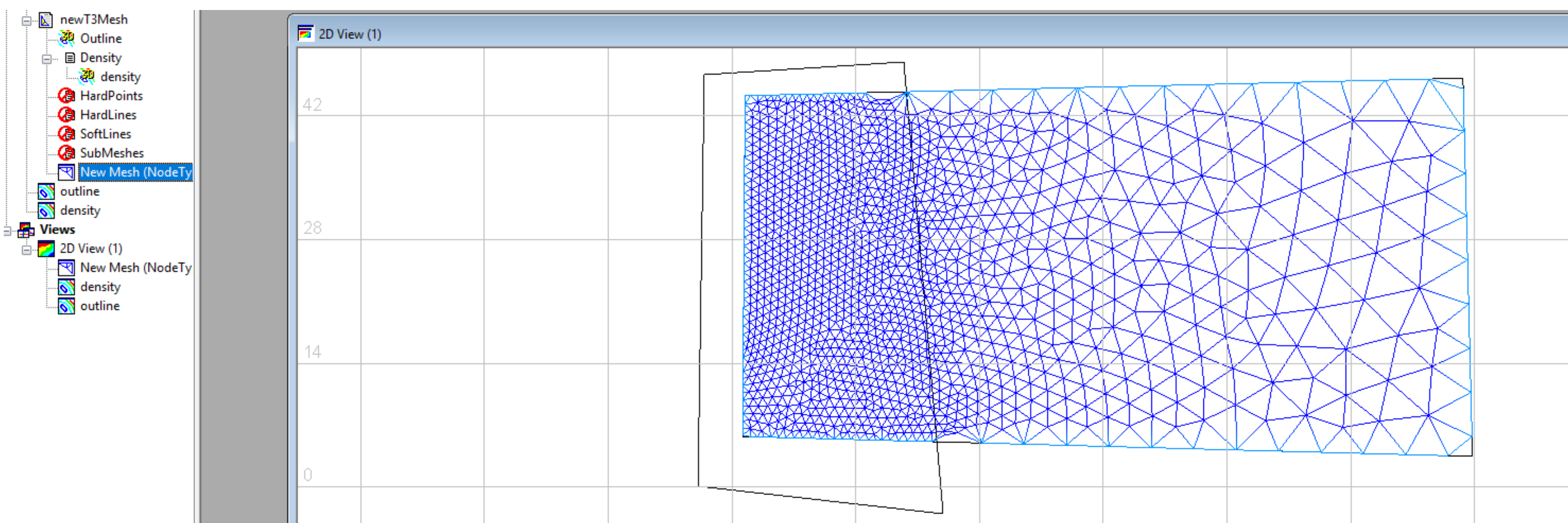
BlueKenue: add a submesh

- Make a submesh (e.g. a channel mesh)
- Drag the mesh to SubMeshes in the t3D mesh generator
- Run



BlueKenue: influencing mesh resolution

- Mesh size influenced by
  - Default edge length
  - Resolution of hard lines
  - Resolution of the edge of submeshes
  - Density
    - Points (leads to smooth variation in density)
    - Polygons (leads to sudden transition in resolution at the boundary)



IMDC

BlueKenue: make smooth meshes

- Make a temporary mesh. Use polygons for density
- Determine edge lengths (Tools -> T3 Mesh -> extract EdgeLengths)
- Click to add points at location with good looking resolution
- Map edge length to point (Tools-> MapObject -> EdgeLengths)
- Make final mesh. Use points for density.

BlueKenue: check the mesh

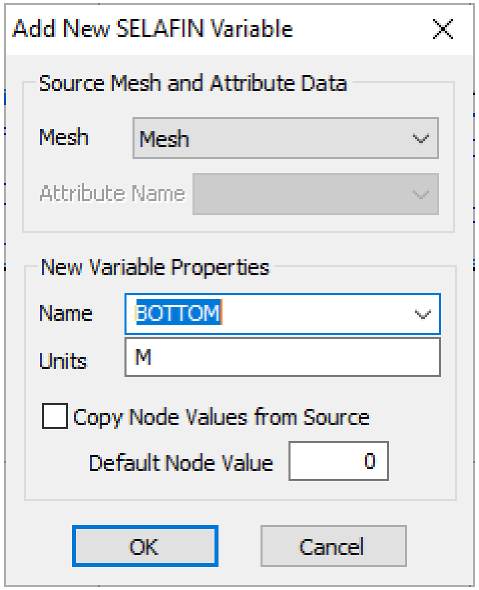
- Check mesh carefully
  - Smooth transitions
  - Weird cells
- Check mesh properties
  - Edit -> T3D Mesh -> Analyse mesh
- Determining boundaries is a good check (shown later)

IMDC

BlueKenue: preparing for simulation

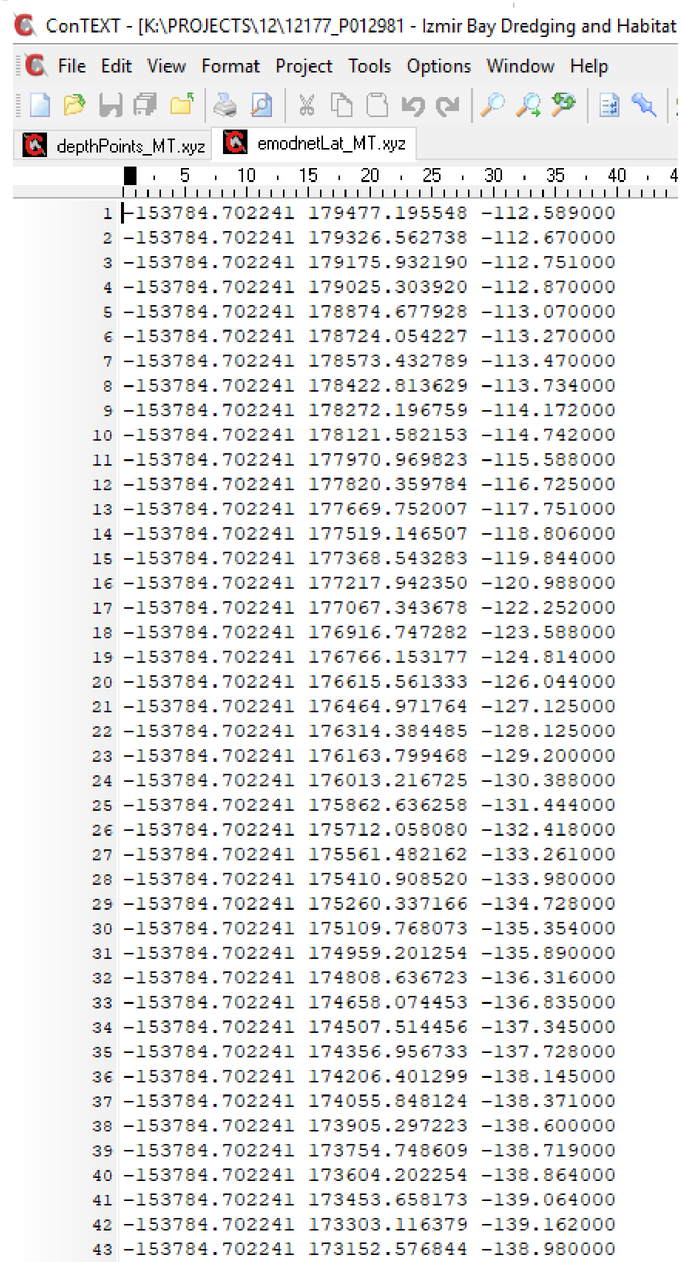
BlueKenue: make a selafin objects

- ->File ->New Selafin object
- Right mouse button -> add variable
- Select the correct input mesh



BlueKenue: interpolate bathymetry (1)

- Prepare bathymetry (.xyz point file)
  - Use e.g. GIS
  - Small files can be made in BlueKenue (clicking and editing)
- Check coordinate systems!

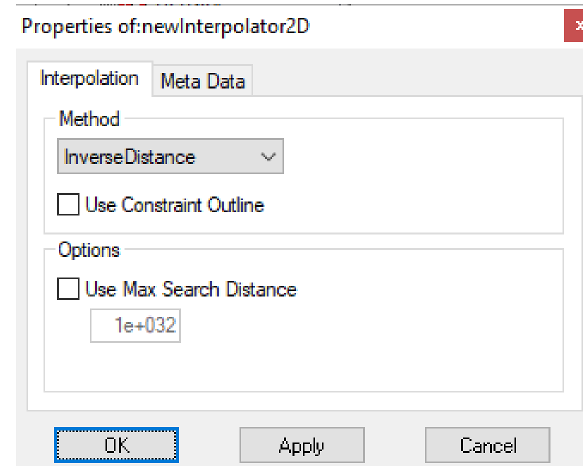

ConTEXT - [K:\PROJECTS\12\12177_P012981 - Izmir Bay Dredging and Habitat

File Edit View Format Project Tools Options Window Help

depthPoints_MT.xyz | emodnetLat_MT.xyz

```
-153784.702241 179477.195548 -112.589000
-153784.702241 179326.562738 -112.670000
-153784.702241 179175.932190 -112.751000
-153784.702241 179025.303920 -112.870000
-153784.702241 178874.677928 -113.070000
-153784.702241 178724.054227 -113.270000
-153784.702241 178573.432789 -113.470000
-153784.702241 178422.813629 -113.734000
-153784.702241 178272.196759 -114.172000
-153784.702241 178121.582153 -114.742000
-153784.702241 177970.969823 -115.588000
-153784.702241 177820.359784 -116.725000
-153784.702241 177669.752007 -117.751000
-153784.702241 177519.146507 -118.806000
-153784.702241 177368.543283 -119.844000
-153784.702241 177217.942350 -120.988000
-153784.702241 177067.343678 -122.252000
-153784.702241 176916.747282 -123.588000
-153784.702241 176766.153177 -124.814000
-153784.702241 176615.561333 -126.044000
-153784.702241 176464.971764 -127.125000
-153784.702241 176314.384485 -128.125000
-153784.702241 176163.799468 -129.200000
-153784.702241 176013.216725 -130.388000
-153784.702241 175862.636258 -131.444000
-153784.702241 175712.058080 -132.418000
-153784.702241 175561.482162 -133.261000
-153784.702241 175410.908520 -133.980000
-153784.702241 175260.337166 -134.728000
-153784.702241 175109.768073 -135.354000
-153784.702241 174959.201254 -135.890000
-153784.702241 174808.636723 -136.316000
-153784.702241 174658.074453 -136.835000
-153784.702241 174507.514456 -137.345000
-153784.702241 174356.956733 -137.728000
-153784.702241 174206.401299 -138.145000
-153784.702241 174055.848124 -138.371000
-153784.702241 173905.297223 -138.600000
-153784.702241 173754.748609 -138.719000
-153784.702241 173604.202254 -138.864000
-153784.702241 173453.658173 -139.064000
-153784.702241 173303.116379 -139.162000
-153784.702241 173152.576844 -138.980000
-153784.702241 173002.039581 -138.699000
```

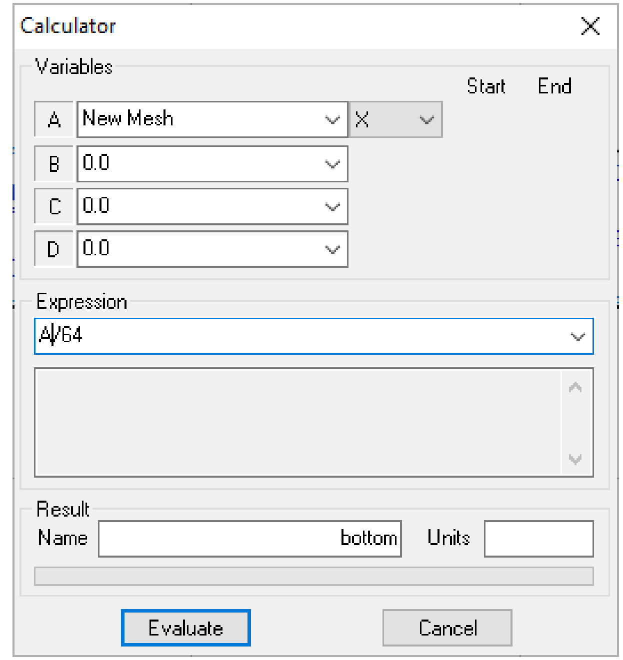
BlueKenue: interpolate bathymetry (2)

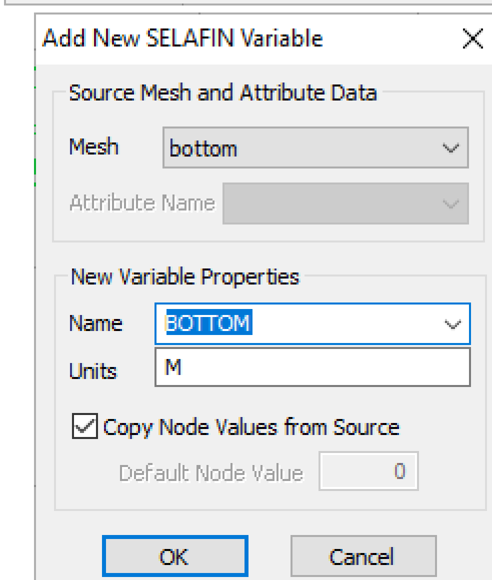


- -> File -> New -> 2D interpolator
- Drag points
- Optionally drag polyline to ConstraintOutline
- Select interpolation method
  - Nearest neighbor (fast, but less accurate/smooth)
  - Linear (fast and smooth; points need to extend outside the mesh)
  - Inverse distance (smoothest; slow for large number of points; points need to extend outside the mesh)
- Select BOTTOM
- Tools -> Map Object -> 2D interpolator
- Check the results (drag to 2D view/3D view)
- **Especially double check the boundaries!**

BlueKenue: use calculator to set bathymetry

- Select BOTTOM
- Tools -> Calculator
- Provide expression
- -> Evaluate
- Check the result
- Add to selafin file:
  - ->Select Salafin
  - ->Add variable-> Select new variable->OK
  - Delete original BOTTOM (if needed)





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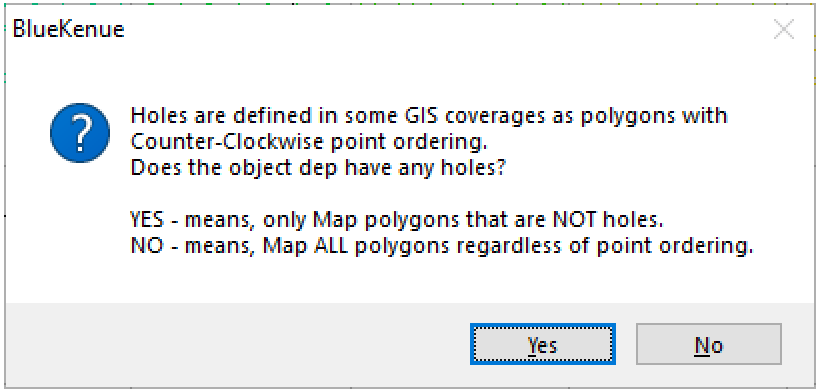
BlueKenue: use polygons for editing bathymetry

- Make a closed polyline
- Give the depth you want as value
- Select BOTTOM
- ->Tools-> Map Object -> polyline -> NO
- Check the results!

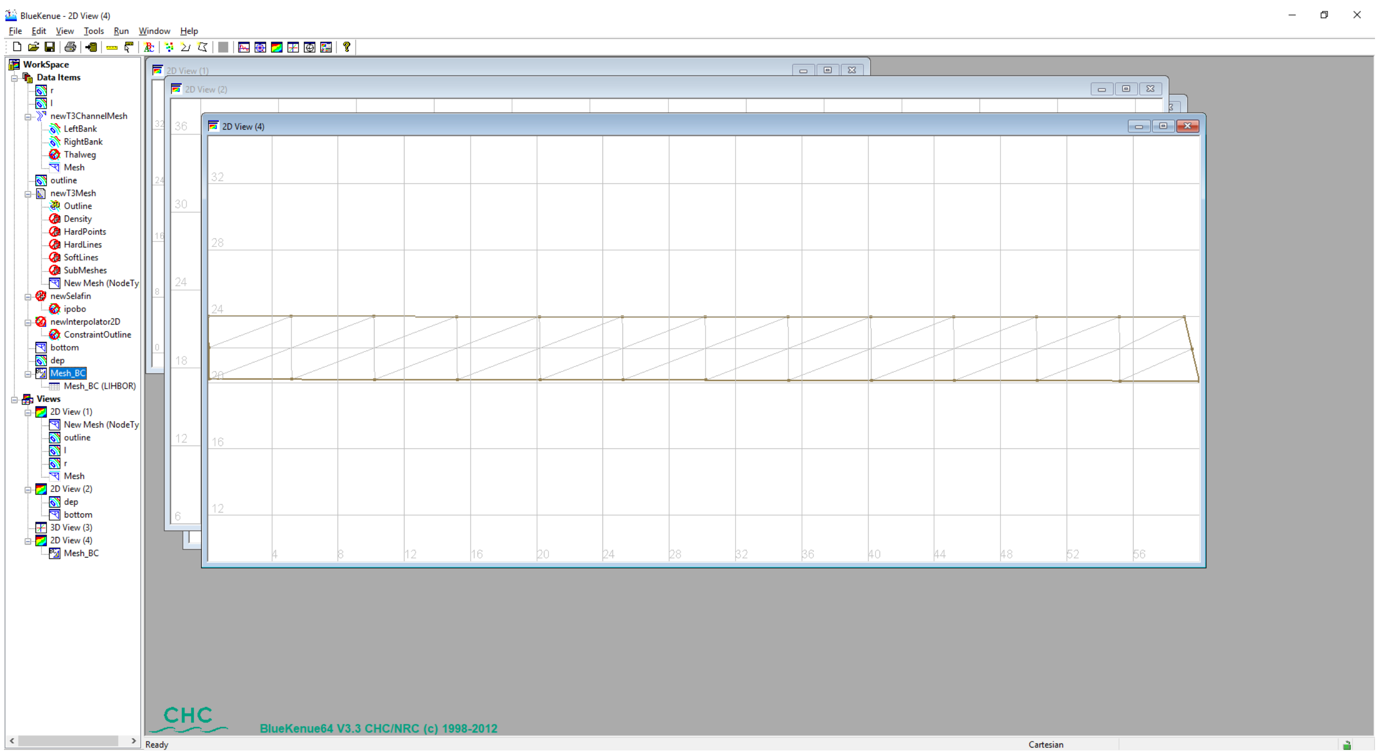


BlueKenue save selafin file

- Click on selafin object
- -> File -> save

BlueKenue: make boundary conditions (1)

- ->File -> New->Boundary conditions (conlim)
- Select your mesh
- Drag object to 2D view



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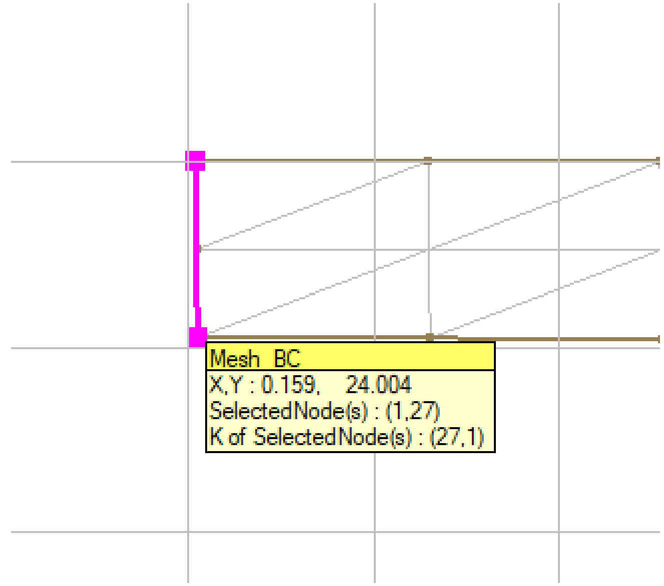
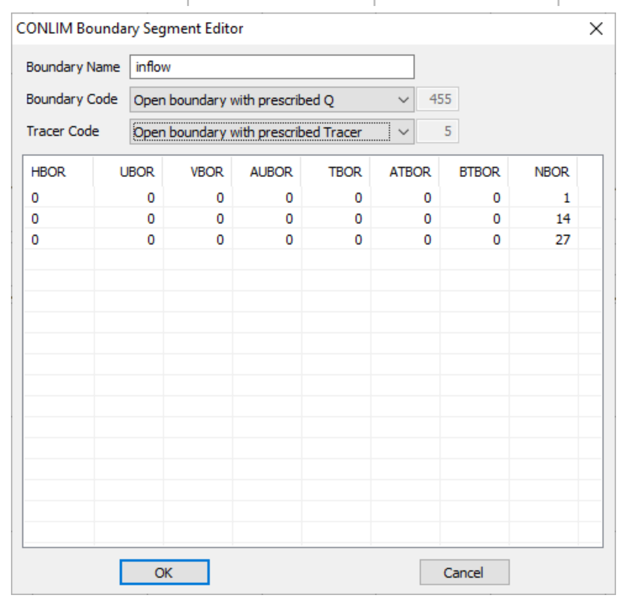
BlueKenue: make boundary conditions (2)

- Select boundary segment
  - click on start point
  - shift+click on end point
  - right mouse button
  - ->Add boundary segment
- Set boundary properties





IMDC

LECTURE 2.1: Project cycle in hydrodynamic modelling

Overview

- Steps in the setup of a hydrodynamic model
- Examples of hydrodynamic modelling

PART 1:
Steps in the setup of a hydrodynamic model

IMDC

Hydrodynamic models: considerations for setup

Which software?

- TELEMAC: unstructured mesh, open-source, somewhat steep learning curve but very suited for custom-made features
- MIKE: easy to use, but less flexible and customisable, expensive
- Delft3D: open-source, curvilinear grid hard to fit in complex shape, new FM version
- Many other suites

One model sufficient?

- When good-quality tidal data is available from TPXO: YES
- When model boundary is situated in shelf sea or coastal sea: NO
- →Latter case: Use or build large-scale tidal propagation model

IMDC

Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

1. Data basis & system knowledge
2. Meshing
3. Boundary conditions
4. Simulation organisation
5. Sensitivity analysis
6. Calibration (strategy)
7. Validation

1. Data Basis & system knowledge

Determine the objective of the model

- Every model is made for a reason/to answer specific questions
- Objective determines choses you make for the model
- Objective determines whether a model is "good" or "bad"
  - "Good": model is suitable to answer the specific questions of a study

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Hydrodynamic Flow modelling

1. Data Basis & system knowledge

- Study the area/literature:
  - What are the main physical processes occurring in the model area?
    - Tide? Stratification (temperature or salinity)? Hurricanes?
  - What processes are not relevant and can be neglected?
  - What are the relevant time scales of these processes?
  - What are the relevant length scales?
  - What are good source of input data for the model

Hydrodynamic Flow modelling

1. Data Basis & system knowledge

- Bathymetry:
  - Coarse data, mainly seas: C-Map, Global Mapper, etc
  - Finer resolution data: grids from echosounding (mainly Belgium, Holland)
- Measurements for calibration or open boundary conditions:
  - Internet, literature
  - Conduct measurement campaign
  - Checks:
    - Units
    - Time format (errors due to UTC/MET etc)
    - Reference levels (LAT, GLLWS, NAP, TAW, ...)
    - Gaps in time series
  - Wind data fields: ECMWF, Metoffice, Hirlam

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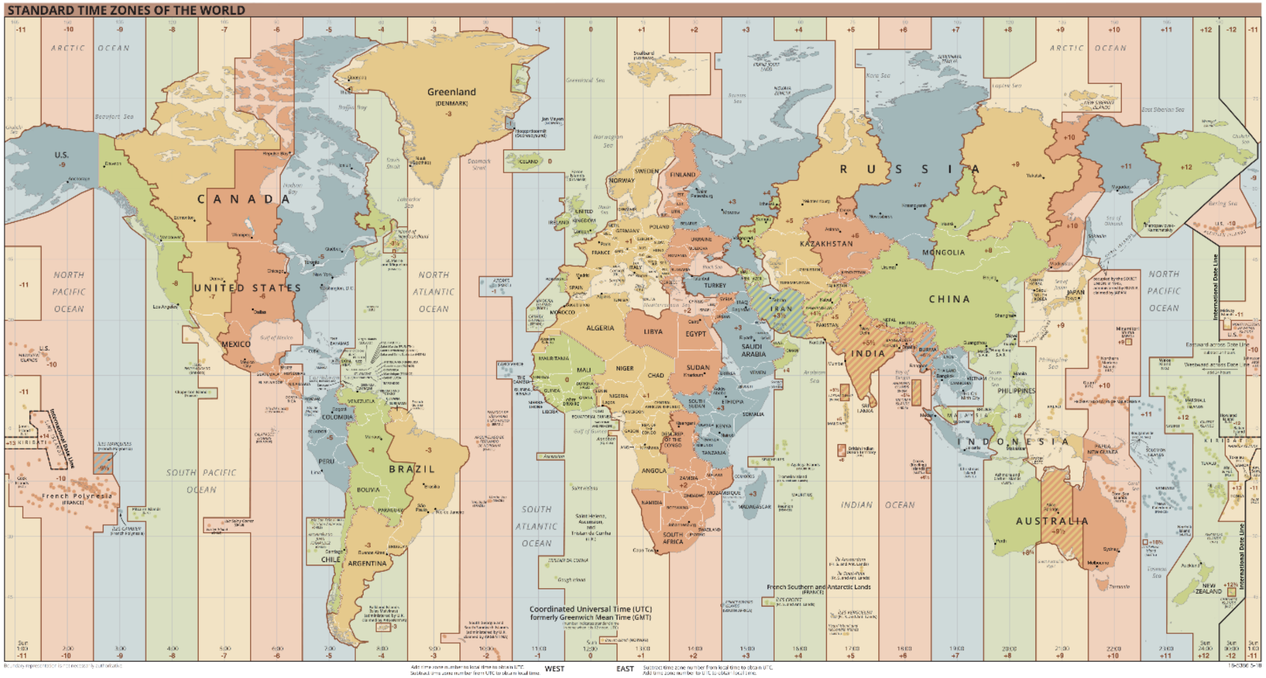
Hydrodynamic Flow modelling

1. Data Basis & system knowledge

- Time format (local time or UTM)



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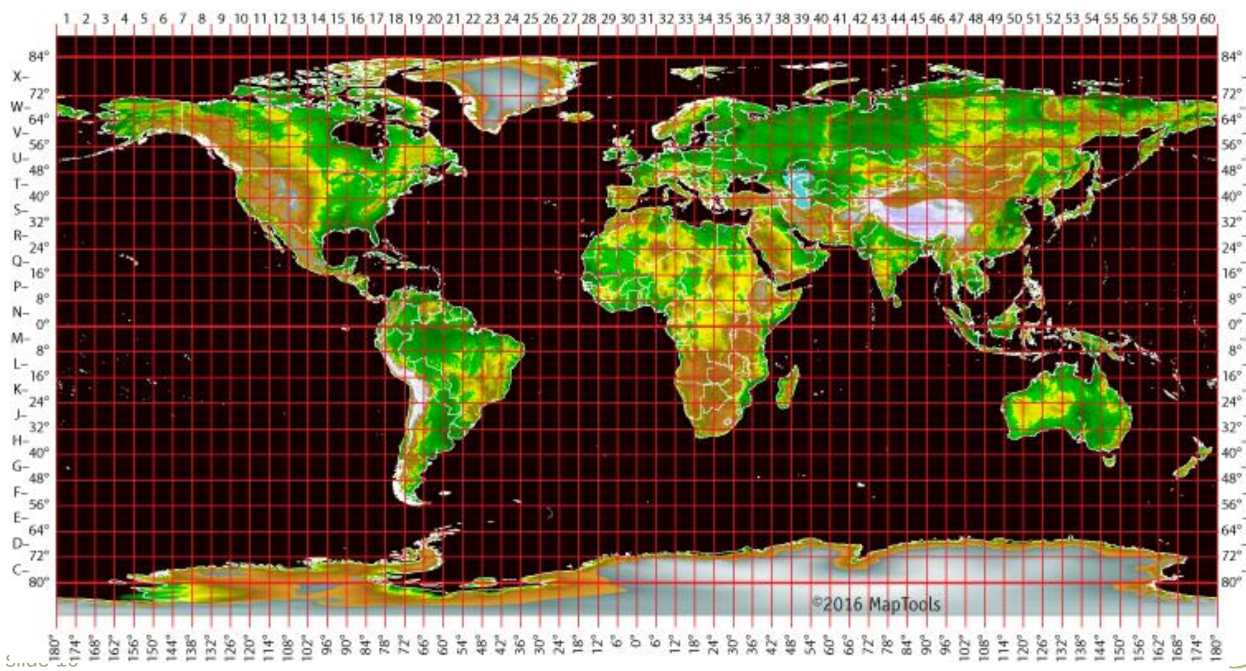
Hydrodynamic Flow modelling

1. Data Basis & system knowledge

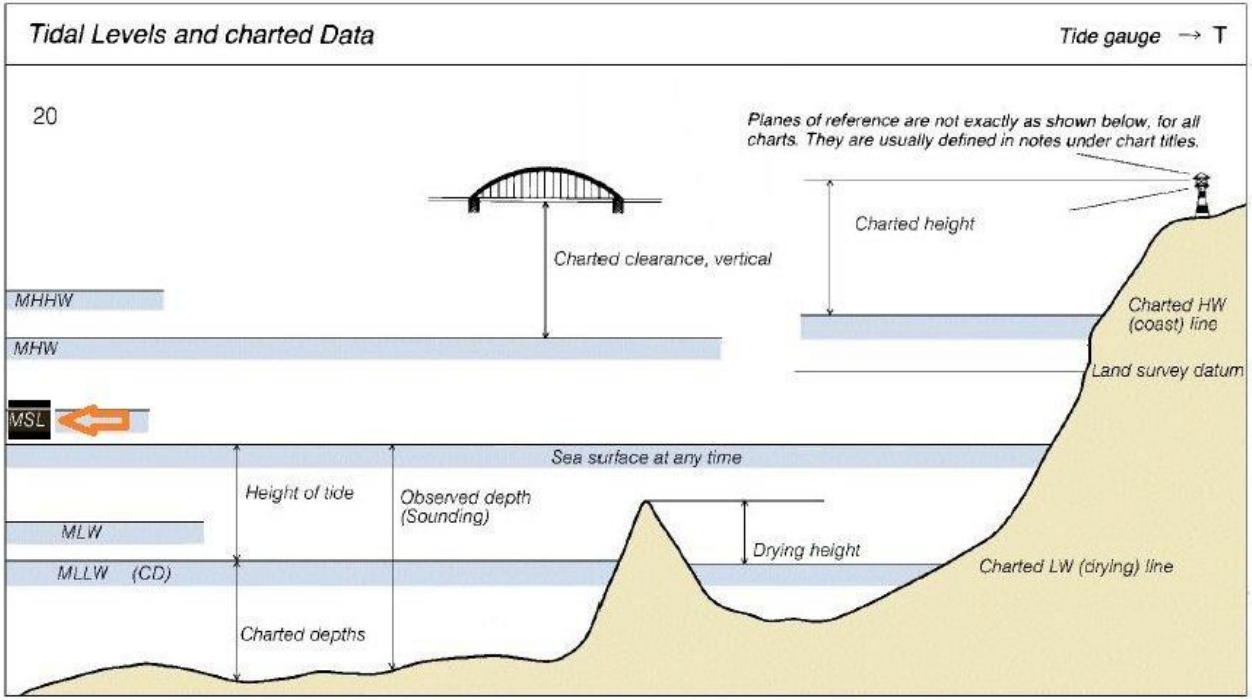
- Horizontal coordinate systems
- Spherical (latitude longitude) or projection (e.g UTM)
- Different reference geoid (ED50 or WGS84)
- Important to use the correct system!



Hydrodynamic Flow modelling

1. Data Basis & system knowledge

- Vertical coordinate systems
- Different systems in use (based on Mean Sea Level or Chart datum)



Hydrodynamic Flow modelling

1. Data Basis & system knowledge

- Data fields of wind and atmospheric pressure
  - ECMWF (free on coarse grid)
  - Metoffice
  - Hirlam
- Harmonic boundaries
  - TOPEX
- Metadata:
  - Time format
  - Coordinate system & reference level
  - Units
  - Source
- System knowledge
  - Which properties does this type of system typically have?

    >> processes, stratification, salinity gradients, tidal propagation, …
  - Using available data and expertise
  - Draw conclusions on model set-up (mesh, dimensions, processes, etc)

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Hydrodynamic Flow modelling

2. Meshing

- General
  - Dimensions:
    - Only add a dimension when there is variation over this dimension. There are more options than 3D, 2DH, 2DV, 1DV
    - Locate open boundaries far from AOI
  - Resolution
    - Think in gradients: refine where gradients occur in flow velocity, salinity, temperature, sediment concentration.
    - Vertically:
      - bottom boundary layer: thin layer at bed, multiply thickness with factor for each layer above
      - wind induced currents: thinner layer near surface
    - Horizontally: provide enough cells across plumes, channels, steep bottom slopes, ...
    - Outside AOI: minimum resolution needed to solve large-scale flow (tide)
    - Near AOI: gradual refinement towards AOI
    - In AOI: use cell size specifically needed for resolving of details

IMDC

Hydrodynamic Flow modelling

2. Meshing

- General
  - Mesh independency principle
    - Large scale solution should not be dependent on (arbitrary) cell size
    - Useful to do a test with half the cell size (if time permits)
      - Can be very short
      - dt =dt/2
      - Results should be almost identical

IMDC

Hydrodynamic Flow modelling

2. Meshing

- Structured mesh (Delft3D, Coherens)
  - Decide: one or more domains (DD)
    - One domain:
      - No specific area of interest (AOI) with refinement needed
      - Area of refinement does not cause excessive cells outside AOI (due to geometry, grid focussing)
  - >1 domain
    - Large differences in cell size needed
    - No coupling far field – near field: Offline nesting
    - Two-way coupling needed: Domain decomposition (Delft3D)
      - e.g. scalar transport with tide
  - Grid quality to check:
    - Orthogonality
    - Smoothness
    - CFL number

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Hydrodynamic Flow modelling

2. Meshing

- Unstructured mesh (Telemac, Mike21FM, Fluent)
  - No need for multiple domains (far field in very coarse resolution)
  - Use advantages unstructured grid to:
    - Provide high resolution where needed, save cells outside AOI
    - Follow depth contours with ‘soft lines’
    - Follow coastlines accurately (detailed land boundary)
    - Follow river thalweg or tidal channels
  - Grid quality to check:
    - Cells nearly equilateral
    - Smoothness
    - No hidden small cells
    - Double cells
    - Holes

Hydrodynamic Flow modelling

3. Boundary conditions

- Sources:
  - Astronomic: TOPEX
  - Measurements (tide, upstream discharge, ...)
  - Large 'mother model'
- Many different types, most used: water level, velocity, discharge, Riemann, Neumann.
- Large open sea boundaries: water level usually sufficient
- Nesting: Riemann (water levels and currents available everywhere)
- Forcing of strong currents needed: velocity profile (from large model)
- Well-posed mathematical problem subcritical flow: downstream water level, upsteam velocity/discharge.
- Coastline model: Neumann (dh/dx) at cross shore bnd, water level at offshore bnd.
- Supercritical flow upstream: velocity+water level
- Wind important? Size domain=important
  - < 500 km: uniform wind ok
  - >500 km: wind field may be needed for cyclones etc

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Hydrodynamic Flow modelling

4. Simulation organisation

- Keep note of all simulations (calculation memo)
  >> Can be Excel sheet with:
  - 1 row per simulation
  - In columns:
    - Based on which previous simulation? (ref run)
    - Change(s) in parameter settings/grid/time/… compared to ref run
    - Remarks
- Each simulation in separate folder
  - Avoids overwriting input files of earlier simulations
  - Avoids double work

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Hydrodynamic Flow modelling

5. Sensitivity analysis

- Of model parameters
  - Bed roughness: uniform
  - Turbulent viscosity: uniform or subgrid model (k-ε, Smagorinsky, algebraic, …)
  - Turbulent diffusivity
  - Determine which (ranges of) parameter settings influence solution
  - Makes calibration more straightforward
  - Num. scheme
- Of boundary conditions
  - Is wind important on tide in your domain? >> test
  - Upstream discharge: yearly averaged value ok? weekly or daily values better? >> test
  - ...
- Always change 1 parameter at a time (to isolate effect of it)

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Hydrodynamic Flow modelling

6. Calibration strategy

- Define parameters to be included (roughness, eddy viscosity, turbulence model, ...)
- Define model result error statistics used in evaluation of results
  - Water level
    - RMSE
    - Bias (general)
    - Vertical error (RMSE on high/low water levels)
    - Horizontal error (RMSE on time of low/high water levels)
    - Absolute deviation on amplitude of M2, M4, S2, K1, O1, ...
    - Absolute deviation on phase of M2, M4, S2, K1, O1, ...
    - Tidal asymmetry M4/M2
    - Flood/ebb dominance: relative phase $2\varphi M2-\varphi M4$
  - Flow velocity
    - RMSE of magnitude |X|
    - MAE
    - RMAE = MAE/<|X|>
    - U, V harmonics ?

$$MAE = \frac{1}{N}\sum_{n=1}^{N}\left|\vec{Y}-\vec{X}\right| = \frac{1}{N}\sum_{n=1}^{N}\sqrt{(Y_x - X_x)^2 + (Y_y - X_y)^2}$$

Model qualification for different RMAE ranges, based on Sutherland et al. (2003).

Model qualification	RMAE
Excellent	<0.2
Good	0.2-0.4
Reasonable/fair	0.4-0.7
Poor	0.7-1.0
Bad	>1.0

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Hydrodynamic Flow modelling

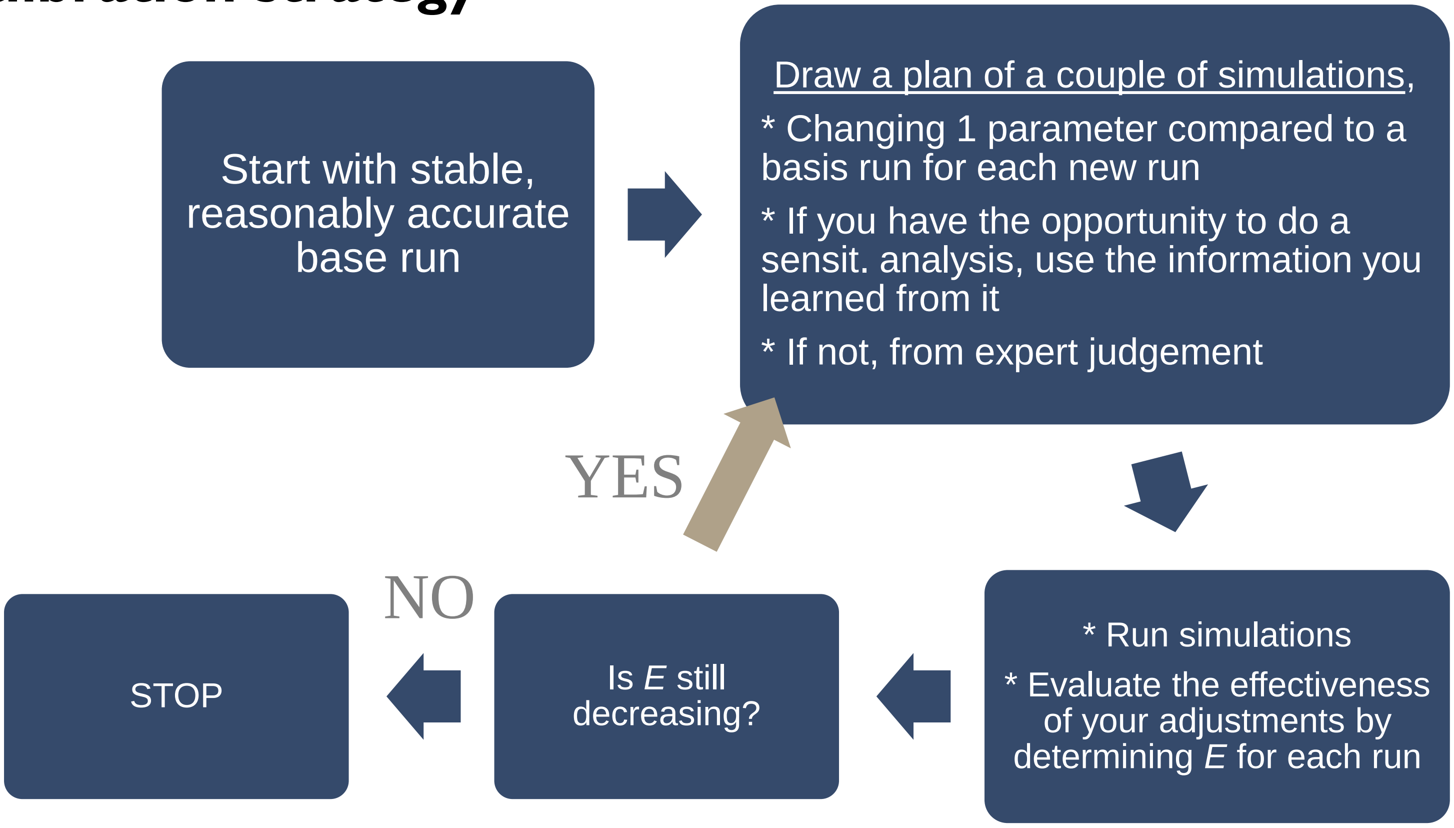
6. Calibration strategy

- Give a weight w_i to each (normalised) model result error statistic s_i

  → $E = \sum_i w_i s_i$

  → E is a general model error level, to be minimised
- w_i depends on specific project interests (e.g. flow velocity for navigation? Sediment transport?, …)
- Make a calibration strategy (see flow chart next slide)
  1. Start with stable, reasonably accurate base run
  2. Draw a plan of a couple of simulations,
  3. Always changing 1 parameter compared to a basis run
  4. If you have the opportunity to do a sensitivity analysis, use the information you learned from it
  5. If not, from expert judgement
  6. Evaluate the effectiveness of your adjustments by determining E for each run
  7. Is E still decreasing? Yes
  8. Take the best run and start from 2.

6. Calibration strategy



Hydrodynamic Flow modelling

6. Calibration strategy

- Tips for transforming observed model anomalies to model adaptations:
  - 'Backtrack' errors from observation point to boundary: does the error develop inside the domain or does it enter from the boundary and propagates?
  - Error on MSL: modify boundary conditions
  - Error on M4: probably due to bathymetry
  - Error on M6: Related to roughness
- On which error statistics to focus??
  - Goal = sediment transport → Flow velocity!
  - Goal = long-term tidal morphology → tidal asymmetry M4/M2 and relative phase $2\varphi M2-\varphi M4$

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Hydrodynamic Flow modelling

7. Validation

- Is quite straightforward:
  - Take an independent data set (different period as calibration data set)
  - Run model for the new period
  - Execute model error analysis
  - Validate or reject the generic character of the model calibration

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PART 2: Examples of hydrodynamic modelling

Hydrodynamic models

Type	Main objective	Input data	Output
Hydrodynamic model	Determine water levels and currents near a project site: - Atmospheric setup - Input for structure design - Navigation windows - Input for transport of salinity, temperature, sediments, …	• Bathymetry • Tides: Time series or harmonic components (boundary conditions) • Time series water level and current near project site (calibration) • Wind fields, atmospheric pressure • Seabed properties: bed roughness	• Water level, flow velocity magnitude and direction

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Transport of sediment and tracers

Type	Main objective	Input data	Output
Modelling of transport of tracers and/or sediment, morphodynamics	• Bed level evolution (erosion-sedim except near coast) • Input for scour protection design • Water quality: turbidity, temperature, salinity (EIA) • Impact of coastal management scenarios, design alternatives, …	• HD model + wave model • Process: If stratification, add salinity and/or temp (+3D!) Sand or mud, short term or long term: • Dredging scenarios • Initial conditions (sal, temp) • Soil parameters: PSD, non-erodible zones • Historic bathymetry data (calibration)	• Erosion-sedim. (except at coast) • Turbidity • Salinity, temperature

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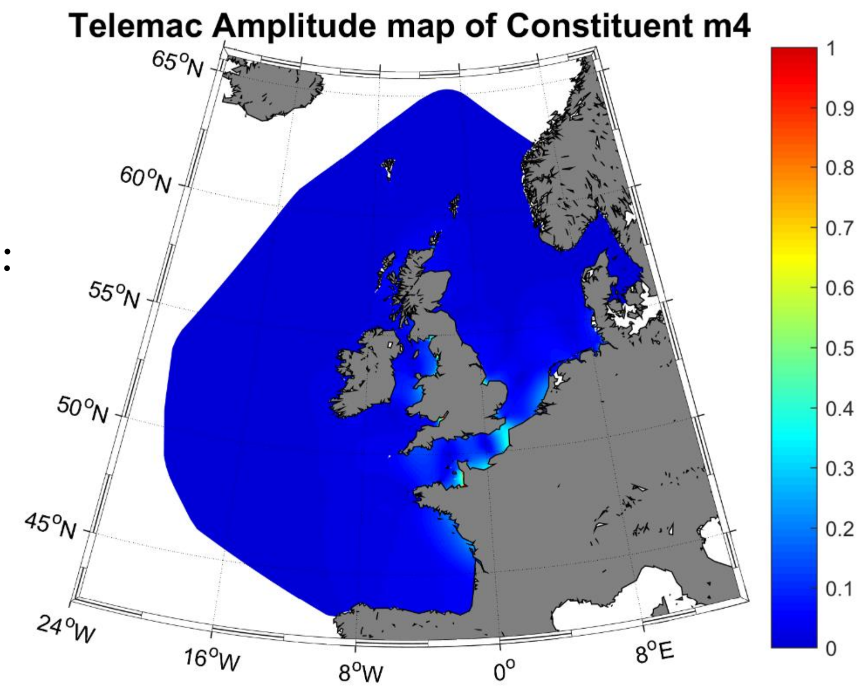
Large-scale tidal propagation models

- Needed for tidal propagation and wind effect
- Tides in deep ocean:
  - defined by M2, S2, O1, K1
  - Well-defined by satellite altimetry results in TPXO database
- Tides while propagating into shallower seas:
  - shallow water components arise: M4, M6, MK3, MN4, S4, …
  - These constituents are not well represented in TPXO
  - Needs to be handled in dedictaed model
- Effect of wind:
  - Large wind fields induce set-up
  - During mild, persistent conditions (e.g. monsoon)
  - During short-term strong wind (storms, cyclones)



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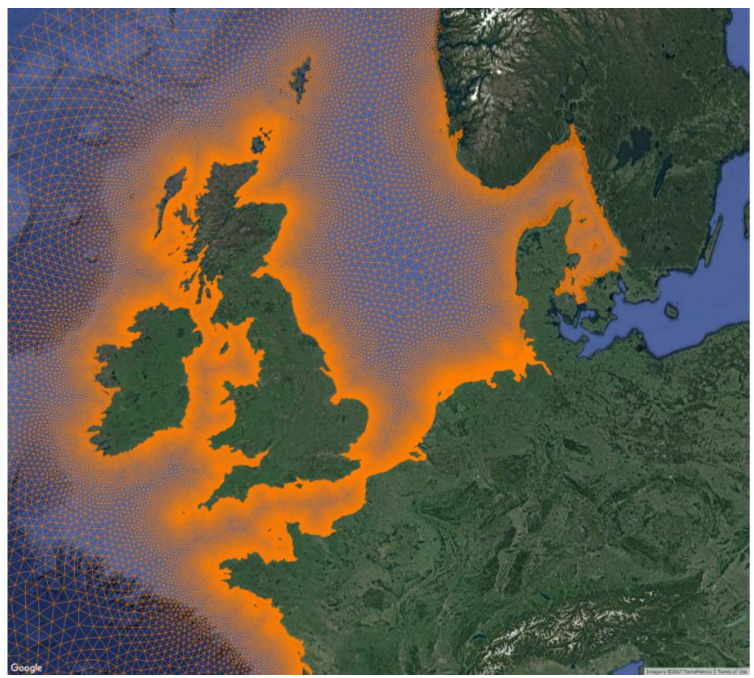
Large-scale tidal propagation models

Models at continental shelf scale:

→ Large-scale tidal propagation models (in-house IMDC, 1000's of km, in 2D)

→ Very efficient (one year tidal flow simulation in ~ 1h on 56 CPU's)

iCSM



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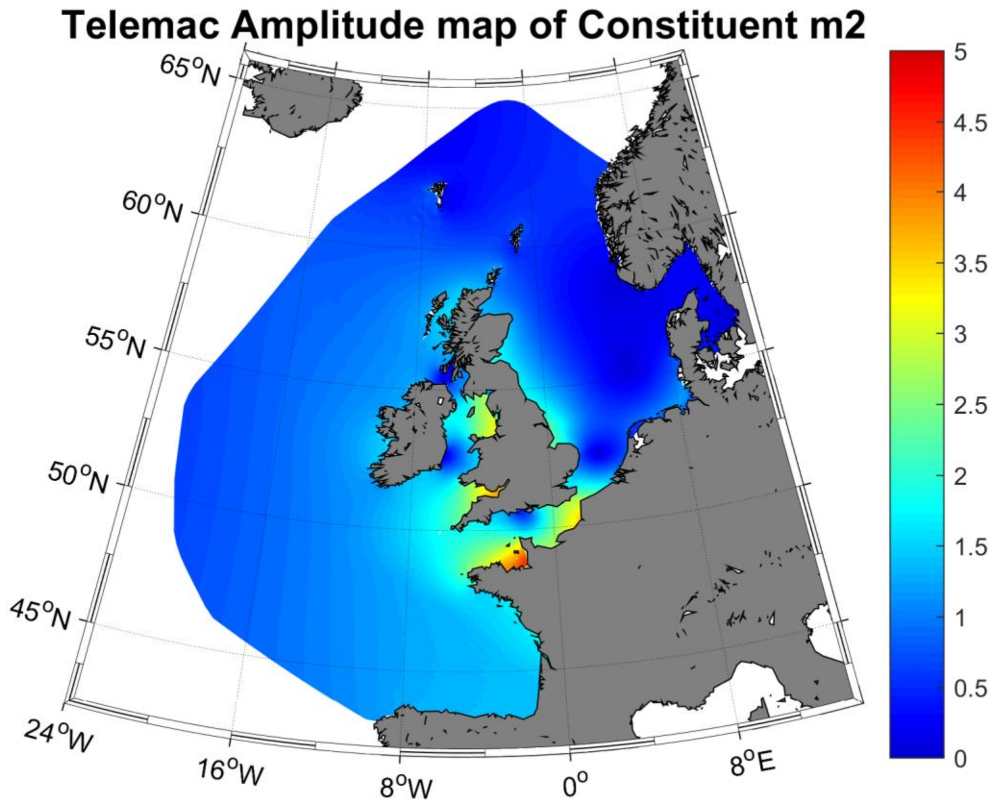
Large-scale tidal propagation models

iCSM



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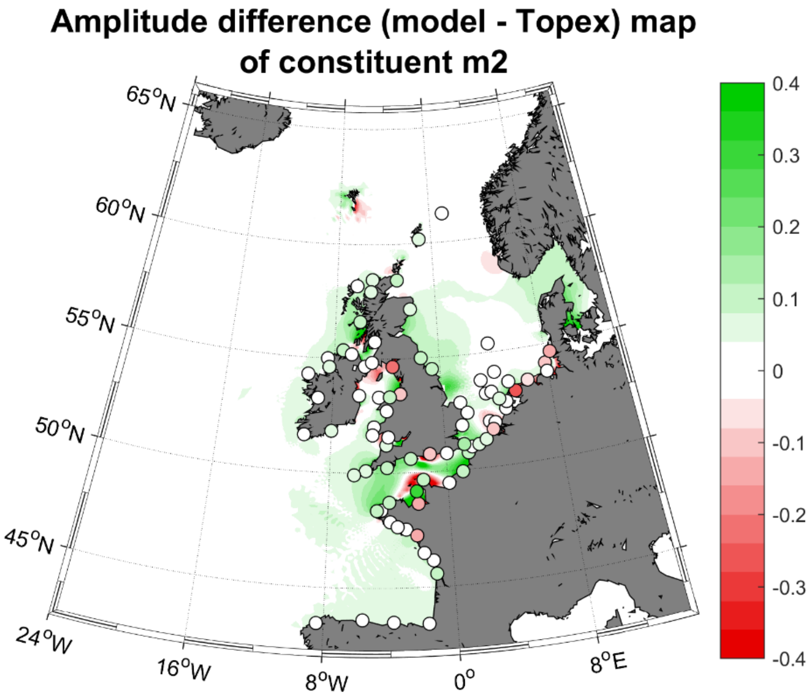
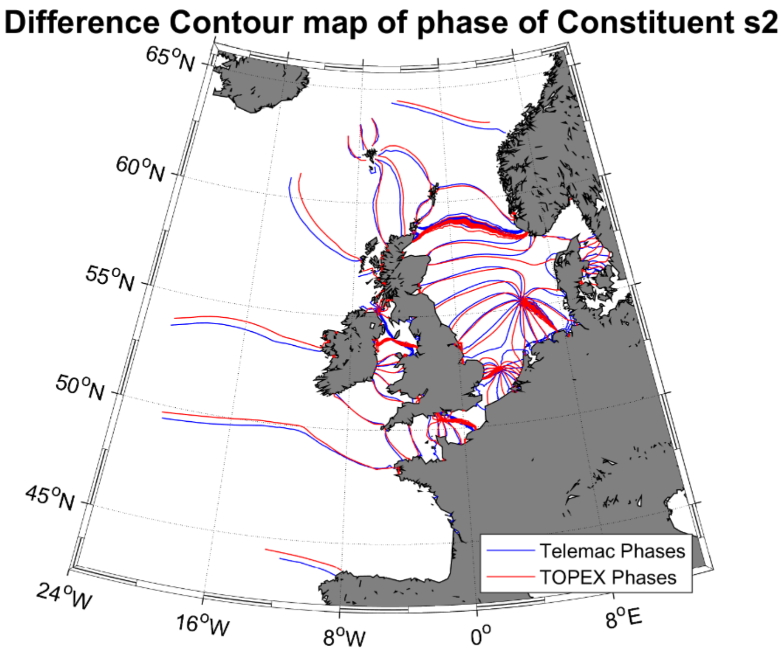
Large-scale tidal propagation models

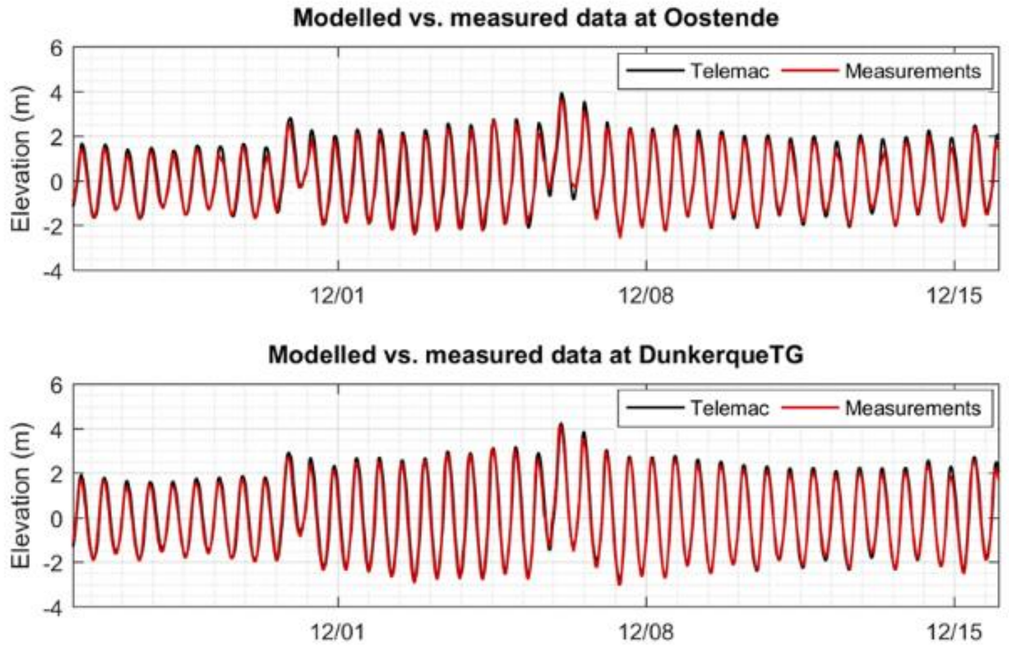
iCSM





Large-scale tidal propagation models

iCSM: performance during storms



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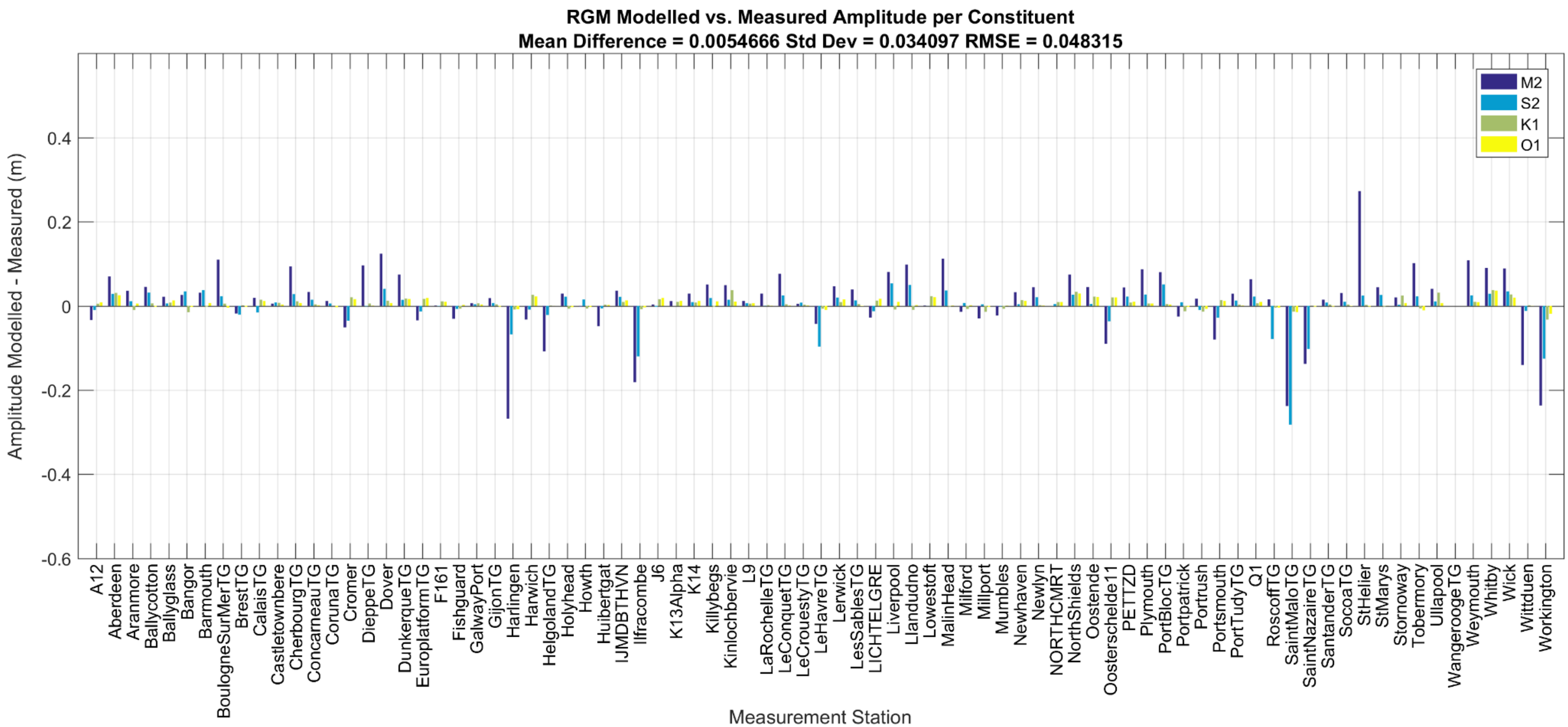
Large-scale tidal propagation models

Example of final calibrated model performance



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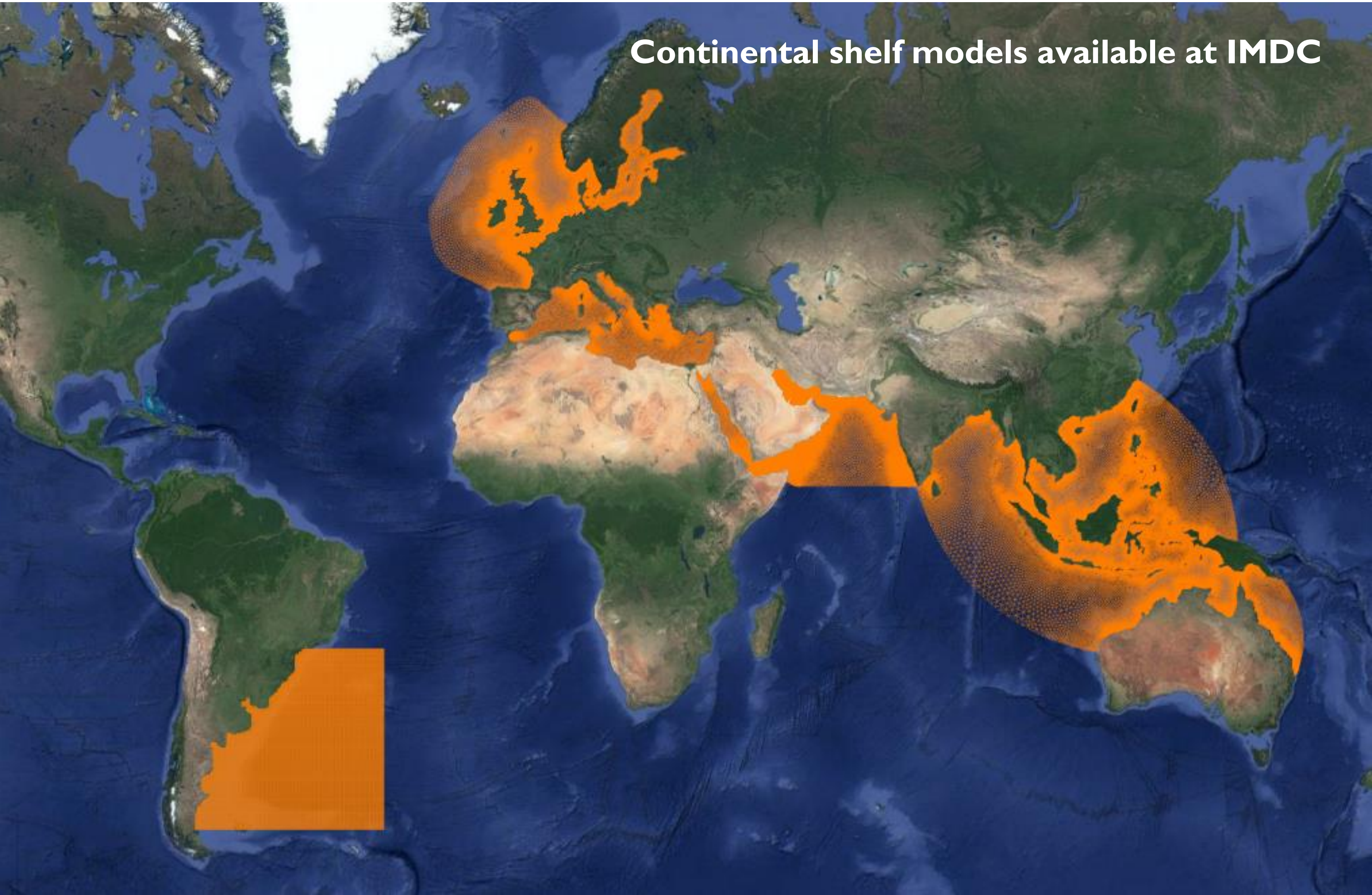
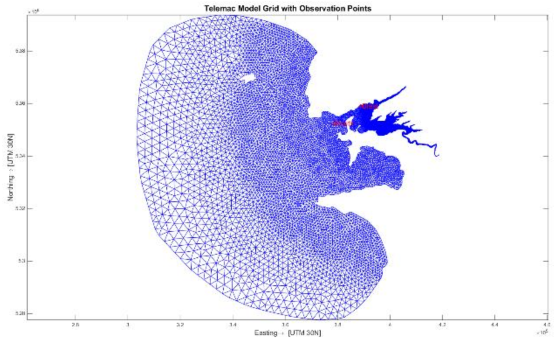
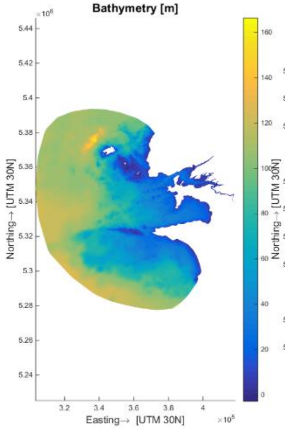
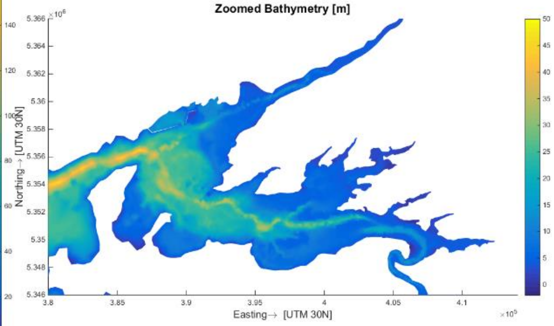

Continental shelf models available at IMDC

Hydrodynamic models: nested models near project site

Hydrodynamic model

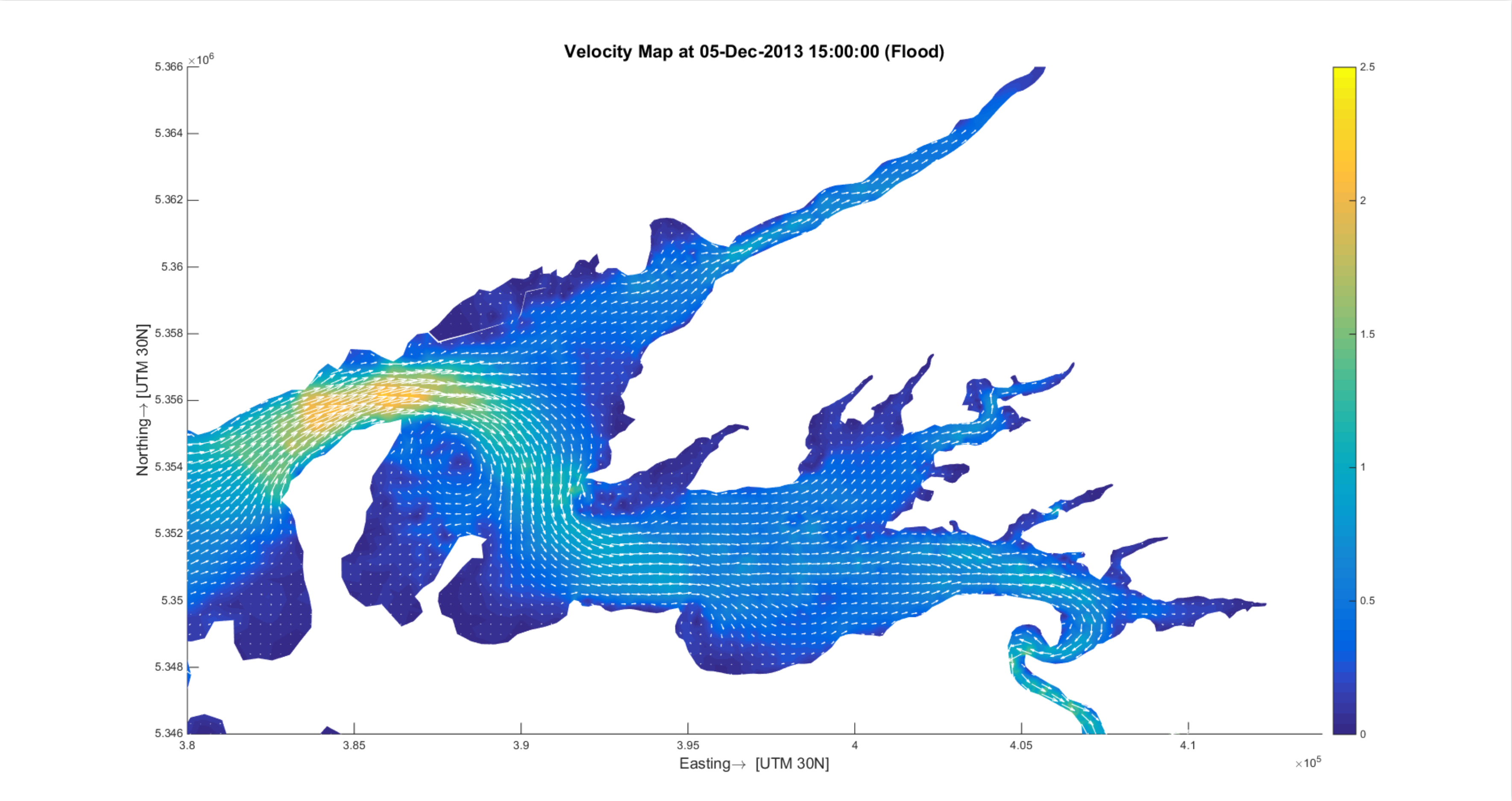






Mesh for model of Rade de Brest, France

Hydrodynamic models: nested models near project site



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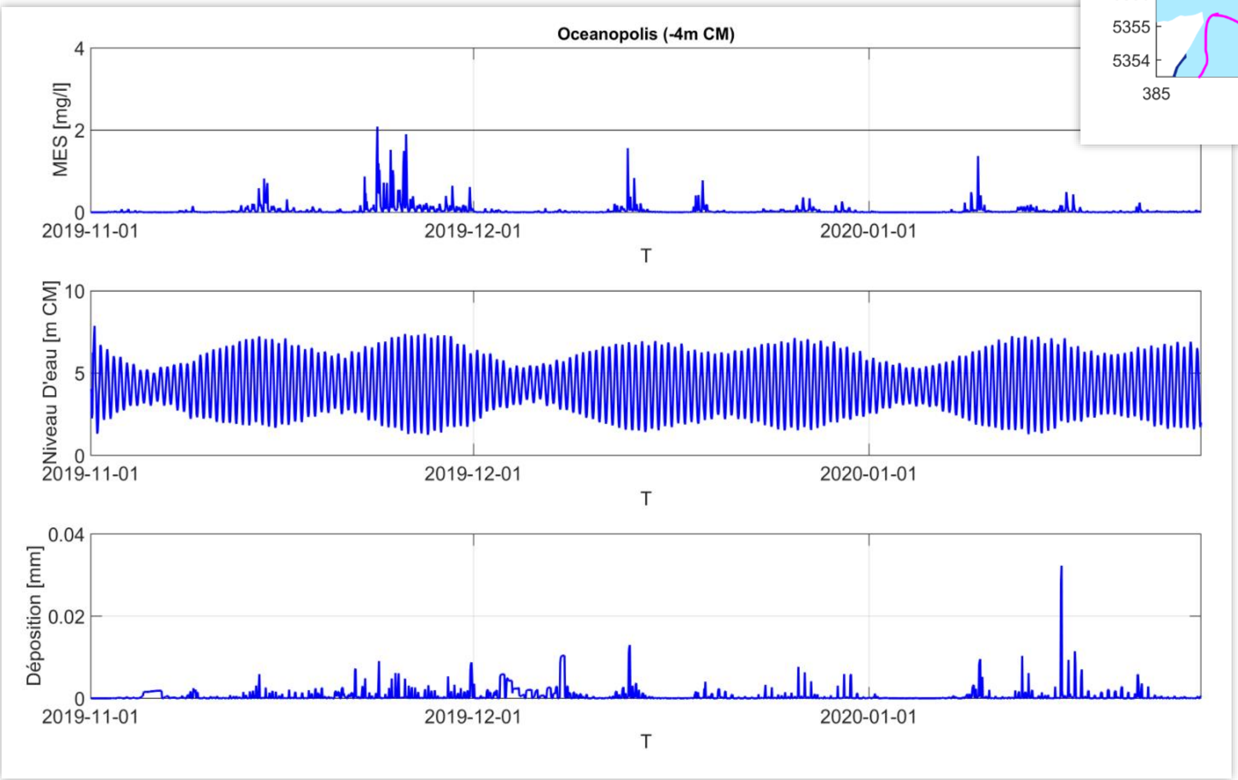
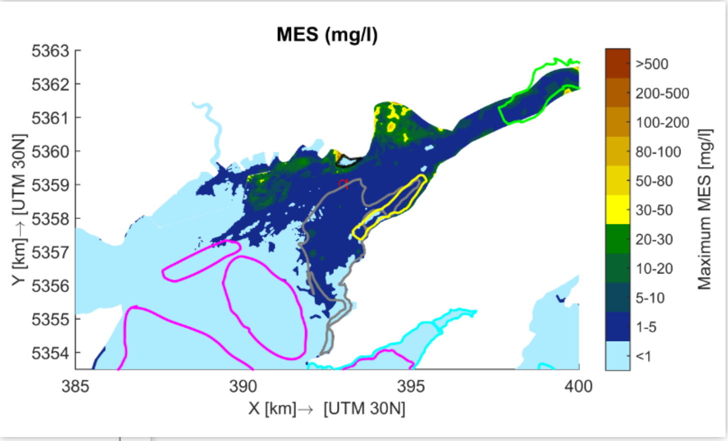
Dredging-induced SSC





Dredge plumes for environmental impact

Dredging-induced SSC

Operational forecasting system Synapps (online, web-based

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Tsunami

Step 1: scenario definition

- The Storegga landslide

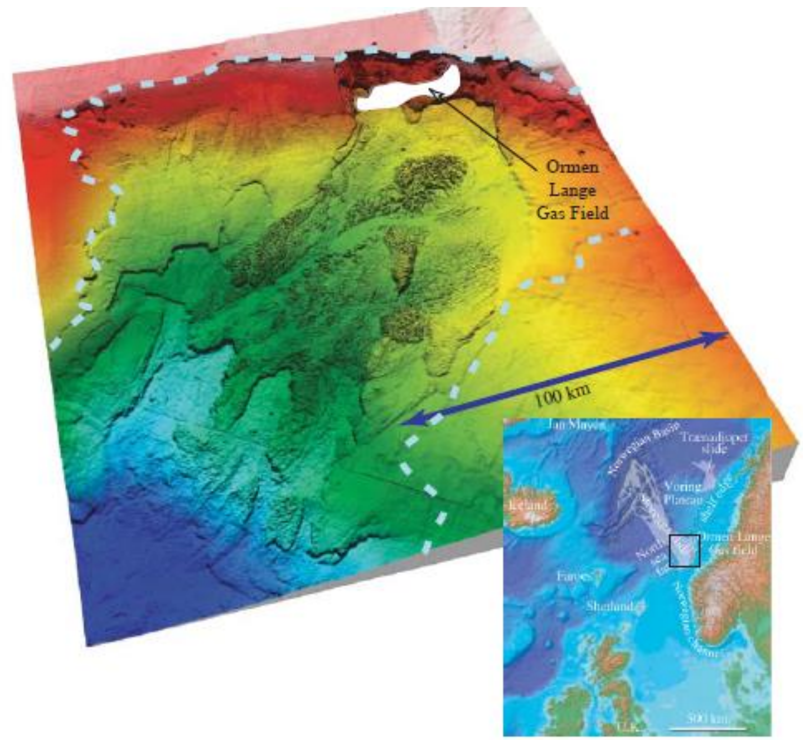
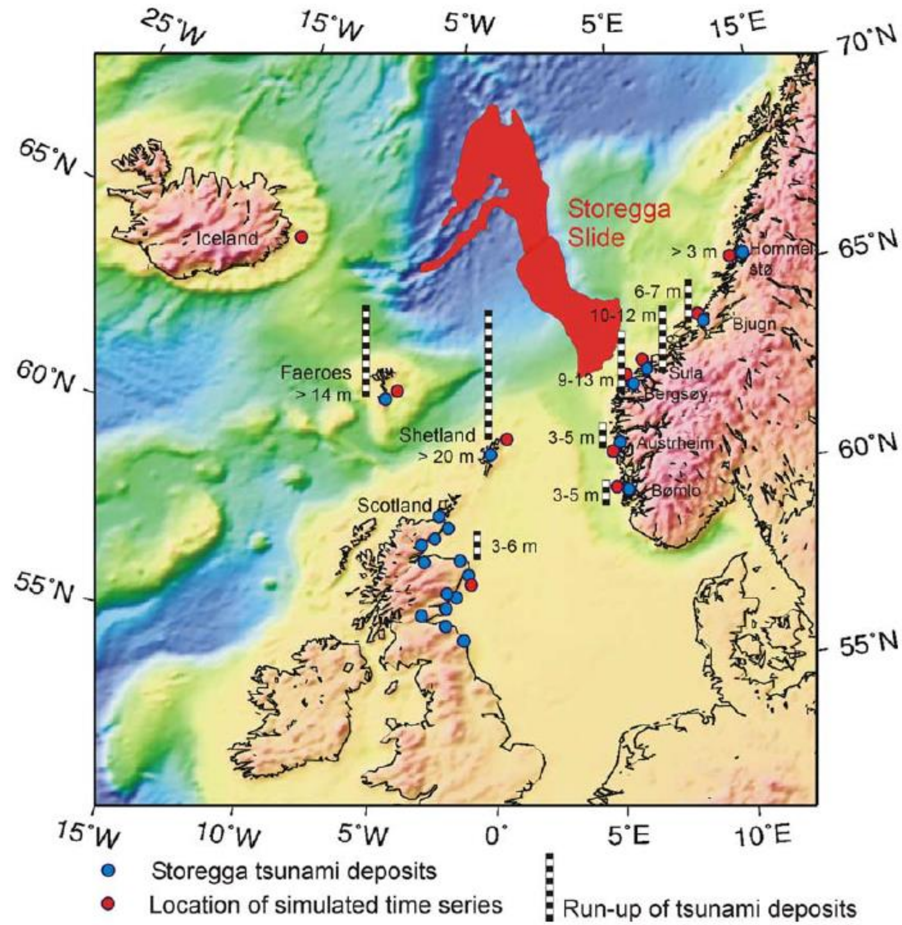
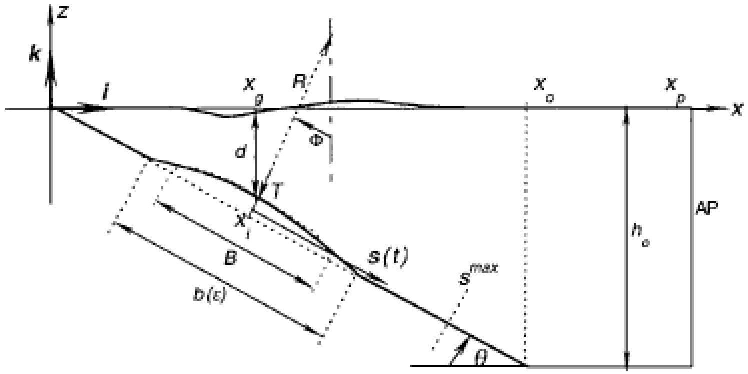


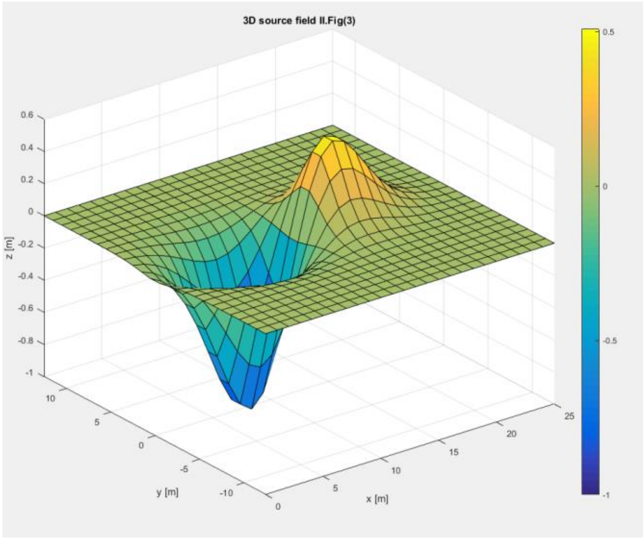
Figure 4. Three-dimensional image of the upper Storegga slide based on swath bathymetric mapping. Dotted line marks limits of landslide. Note the occurrence of multiple bedding-parallel failure planes (best seen bottom left) and the remnants of blocky landslide debris that partially fill much of the upper landslide scar. Image courtesy of Petter Bryn, Norsk Hydro.



Step 2: Source term definition

- Empirical model of Grilli and Watts (2005), Watts et al. (2005) for normal landslides, not giant ones





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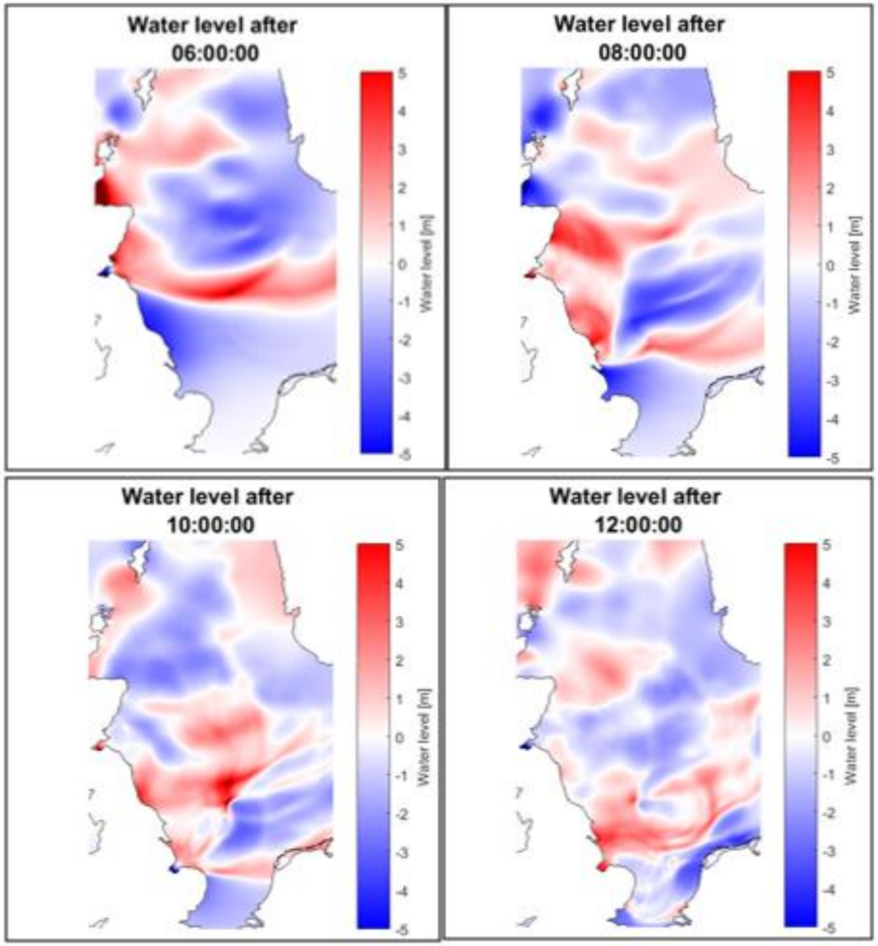
Step 3, 4 and 6: Tsunami propagation, run-up and coastal inundation

Maximum Credible Event



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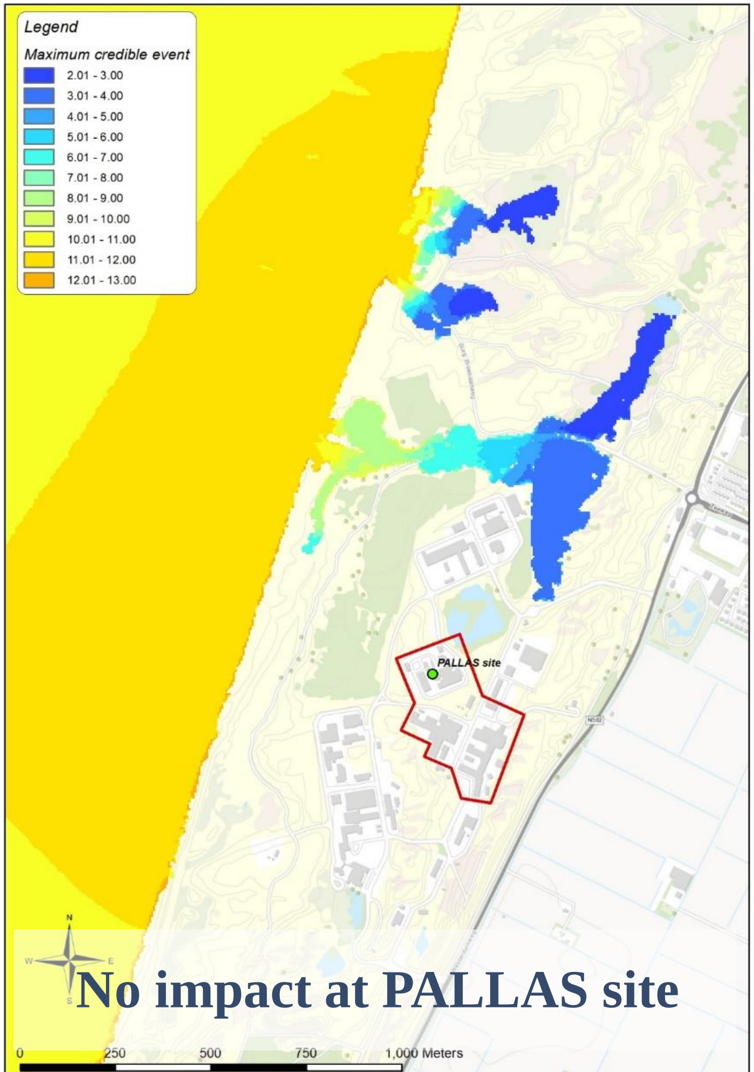
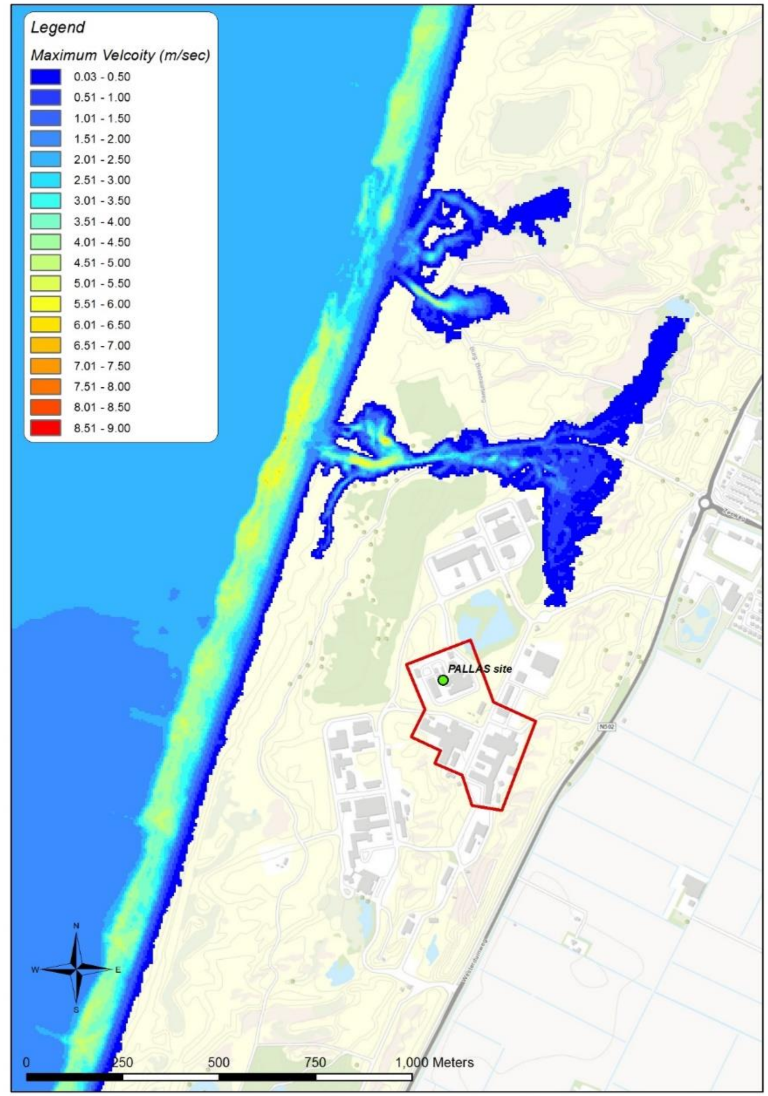
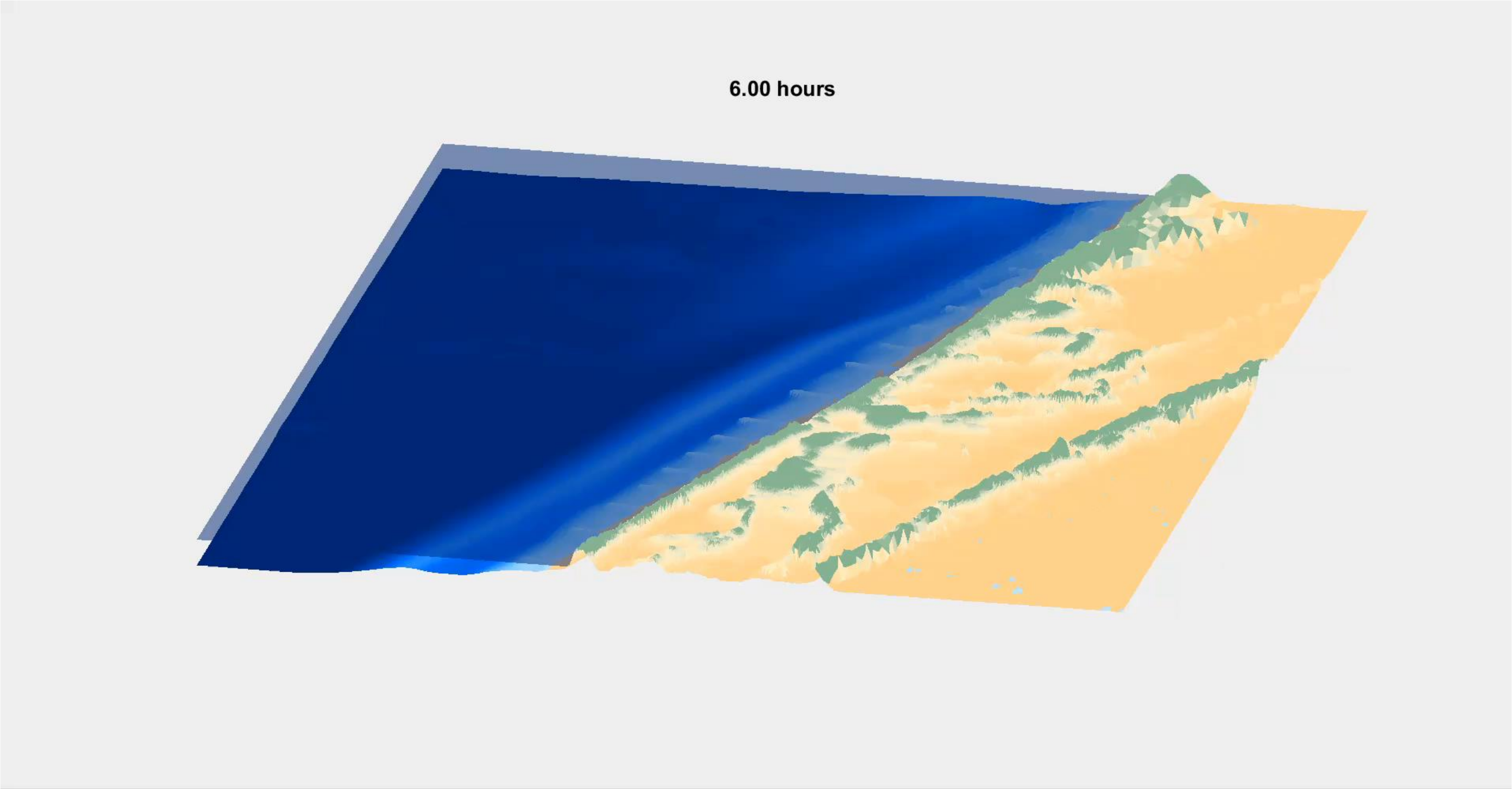
Step 3, 4 and 6: Tsunami propagation, run-up and coastal inundation



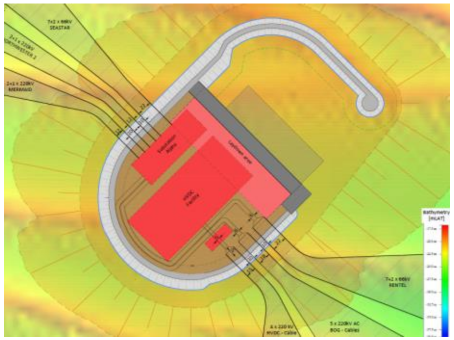


Step 3, 4 and 6: Tsunami propagation, run-up and coastal inundation

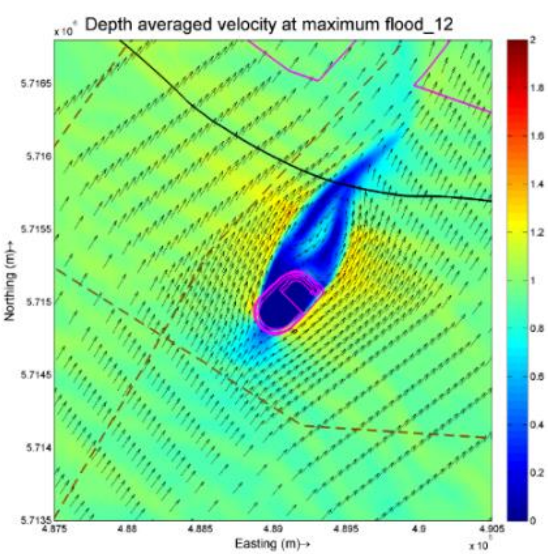


Morphodynamic models for marine developments

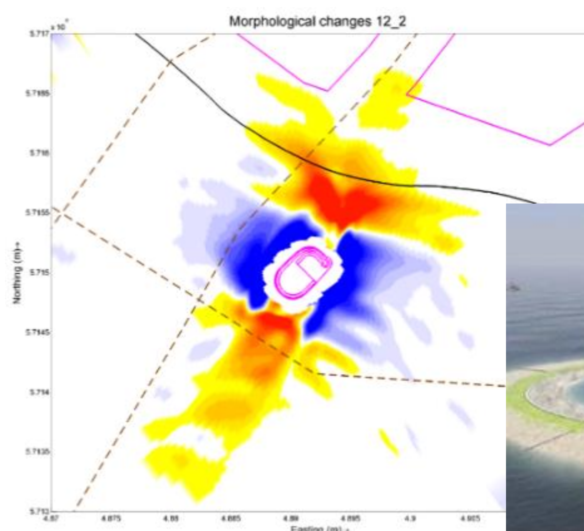
Artificial Island for OHVS



Model for currents



Sediment transport model

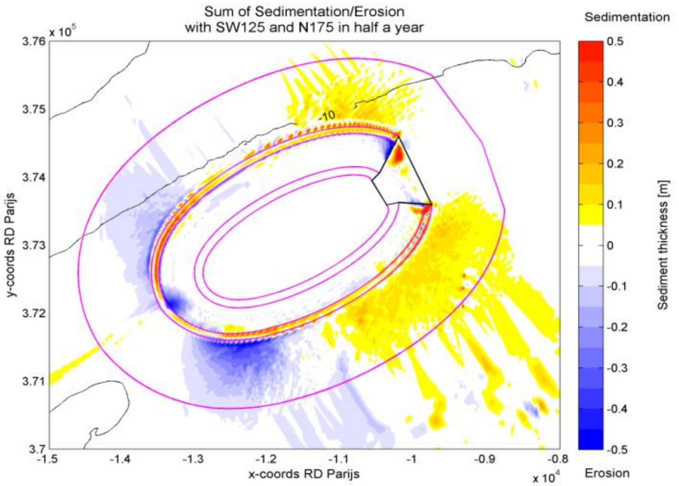


Energy storage island

Morphodynamic models for marine developments

Energy storage island

Erosion/deposition soft coast



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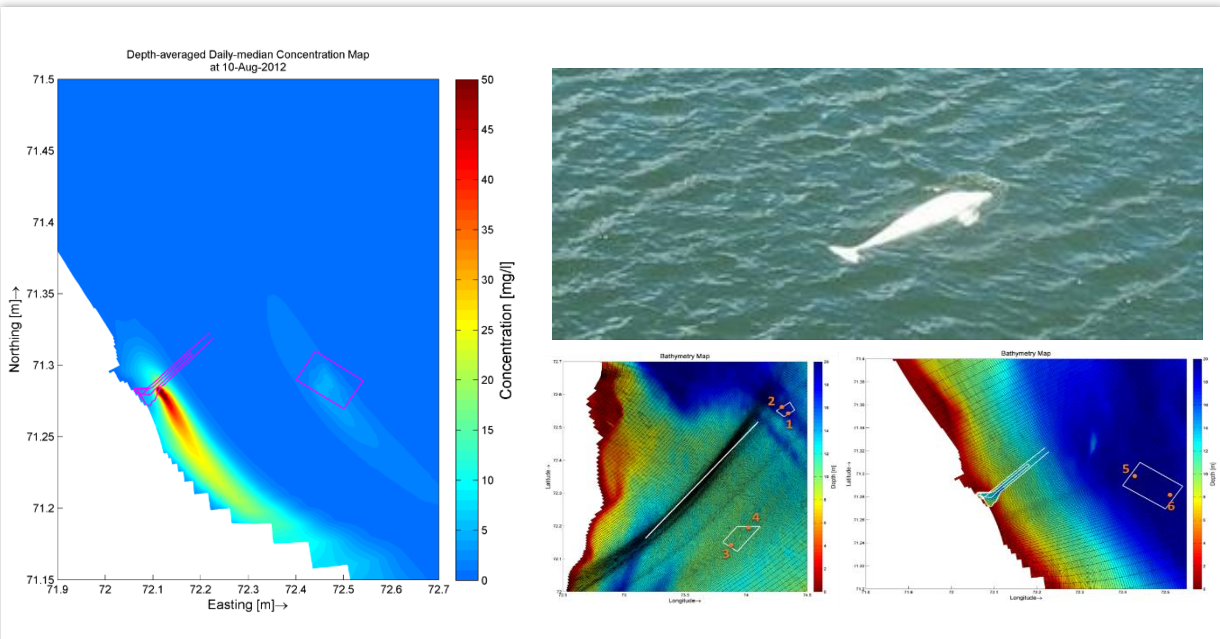
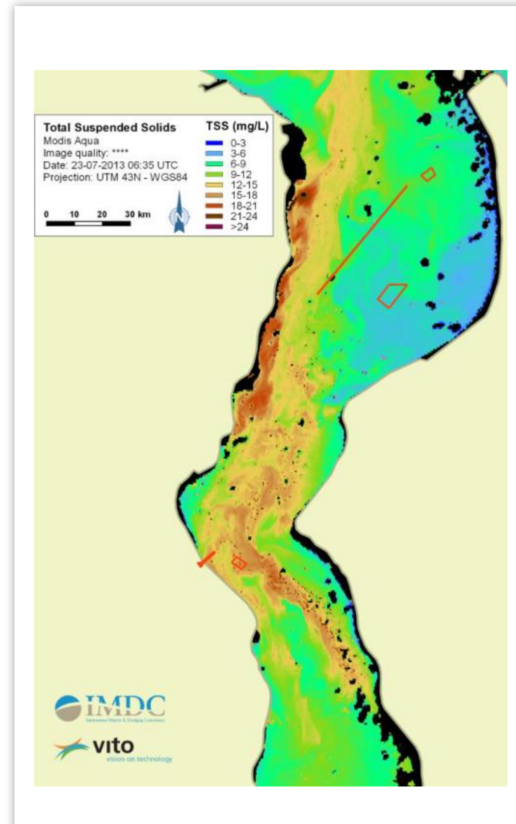
Dredging and Environment

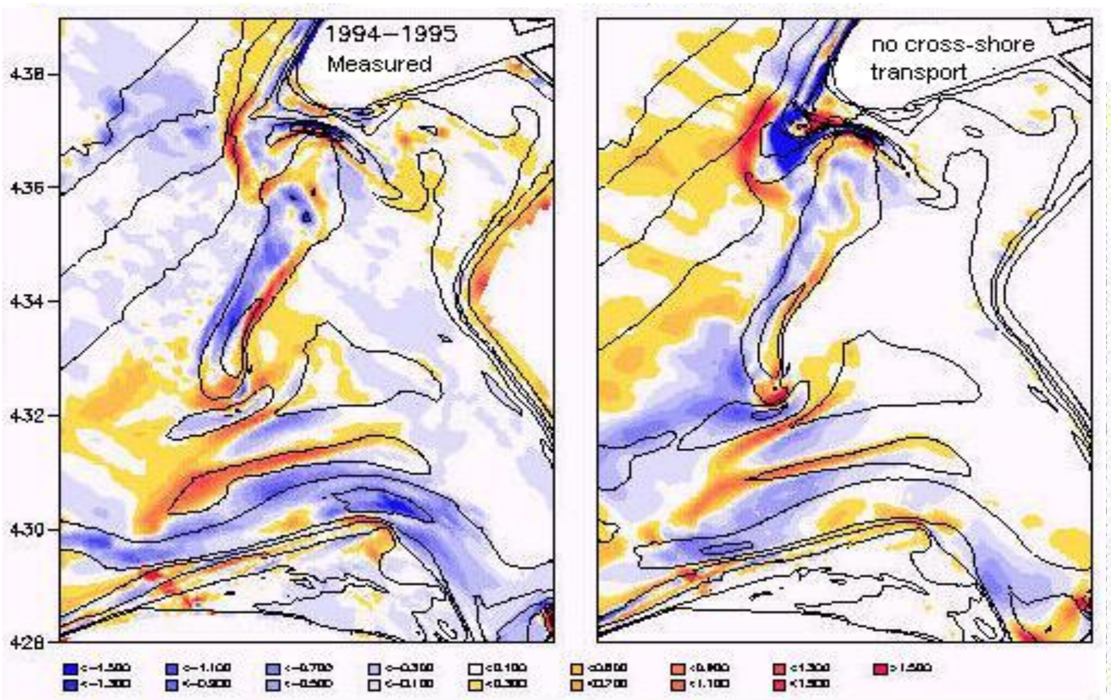
Sabetta Port & Sea Channel Dredging Yamal, Russia

- Environmental Site Engineers
- Remote Sensing of Turbidity 2011-2014
- Sediment Plume & Salinity Intrusion Modelling
- Environmental Monitoring and Mgmt Plans





Morphodynamic model performance



Good performance or not??

Measured and computed depth changes 1994-1995

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?
ANY QUESTIONS ?
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Lecture 2.2: running and visualizing TELEMAC
Alexander Breugem
IMDC

Objective

- Prepare input (steering file)
- Run TELEMAC
- Monitor log-data
- Open the result files in BlueKenue in visualize them

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Overview

- Yesterday
  - Make a mesh+bathymetry (.slf file)
  - Make a boundary conditions file (.cli file)
- Now
  - Copy mesh and boundary conditions to a working directory (e.g c:\test\harbour)
  - Add and edit a steering file (.cas file)
  - Run the model
  - Visualize the data

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Copy data to a working folder

- Copy .cli file to c:\test\harbour
- Copy .slf file to c:\test\harbour
- Copy examples\cas2d.cas to c:\test\harbor
- Rename cas2d.cas to harbour.cas

Cas file

- Steering file (ascii text)
- Must be given as input to executable
- Can be in two languages
  - English
  - French
- Typically in the form of:
  - `parameter = value`
- Parameters are found in the **reference manual**
- Comments are possible `/ This is comment /`
- Multiple values separated by a `;`
- Maximum 72 characters on a line
- Ends with `&fin`

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Edit the .cas file (1)

- Open examples\cas2d.cas
  - Review settings
  - Add filenames

```
PARALLEL PROCESSORS = 1
/---------------------------------------------------------------------/
/    TELEMAC-2D      -  EXAMPLE CAS FILE                              /
/                                                              /
/---------------------------------------------------------------------/
/
/---------------------------------------------
/  COMPUTER INFORMATIONS
/---------------------------------------------
/
GEOMETRY FILE                     = harbour.slf
BOUNDARY CONDITIONS FILE          = harbour.cli
RESULTS FILE                      = result.slf
/
/---------------------------------------------
/  GENERAL INFORMATIONS - OUTPUTS
/---------------------------------------------
/
TITLE                             = 'EXAMPLE'
VARIABLES FOR GRAPHIC PRINTOUTS = 'U,V,H,B,S'
GRAPHIC PRINTOUT PERIOD           = 50
LISTING PRINTOUT PERIOD           = 50
TIME STEP                         = 0.2
NUMBER OF TIME STEPS              = 1000
MASS-BALANCE                      = YES
INFORMATION ABOUT SOLVER          = YES
/
/---------------------------------------------
```


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Edit the .cas file (2)

- Check boundary numbering
  - Open harbour.cli
  - Look for discharge boundary. First or second?
- Open harbour.cas
  - Edit boundary conditions

```
/---------------------------------------------------
/   BOUNDARY CONDITIONS
/---------------------------------------------------
/
PRESCRIBED FLOWRATES                  = 0. ; 200.0
PRESCRIBED ELEVATIONS                 = 0. ; 0.
/
/---------------------------------------------------
/   PHYSICAL PARAMETERS
/---------------------------------------------------
/
TURBULENCE MODEL                      = 4
LAW OF BOTTOM FRICTION                = 5
FRICTION COEFFICIENT                  = 0.015D0
/
```

Edit .cas file (3)

- Open harbour.cas
- Change time step (CFL?)
- Change TITLE
- Change printout period
- Change number of time steps

```
/---------------------------------------------------------------
/   GENERAL INFORMATIONS - OUTPUTS
/---------------------------------------------------------------
/
TITLE                              = 'HARBOUR'
VARIABLES FOR GRAPHIC PRINTOUTS    = 'U,V,H,B,S'
GRAPHIC PRINTOUT PERIOD            = 300
LISTING PRINTOUT PERIOD            = 300
TIME STEP                          = 1.0
NUMBER OF TIME STEPS               = 1800
MASS-BALANCE                       = YES
INFORMATION ABOUT SOLVER           = YES
/
```


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Steps performed by TELEMAC (python scripts)

1. Make a working directory
2. Copy all input to the working directory
3. Do a domain decomposition (PARTEL)
4. Run TELEMAC in parallel
   - One output file per processor (T3DRES, T3DHYD)
   - One log file per processor
5. Merge output files (GRETEL)
6. Copy data back to main directory
7. Delete working directory

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Running TELEMAC (1)

- Open anaconda prompt
- Go to telemac setup directory
  - cd c:\test\harbour
- Information on running TELEMAC

Anaconda Prompt

```
(base) D:\>python %PYTHONPATH%\runcode.py --help

Loading Options and Configurations
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Usage: runcode.py [options]
use -h for more help.

Options:
  -h, --help            show this help message and exit
  -c CONFIGNAME, --configname=CONFIGNAME
                        specify configuration name, default is randomly found
                        in the configuration file
  -f CONFIGFILE, --configfile=CONFIGFILE
                        specify configuration file, default is systel.cfg
  -r ROOTDIR, --rootdir=ROOTDIR
                        specify the root, default is taken from config file
  -s, --sortiefile      specify whether there is a sortie file, default is no
  -t, --tmpdirectory    specify whether the temporary directory is removed,
                        default is yes
  -x, --compileonly     specify whether to only create an executable but not
                        run, default is no
  -w WDIR, --workdirectory=WDIR
                        specify whether to re-run within a defined
                        subdirectory
  --nozip               specify whether to zip the extra sortie file if
                        simulation in parallel
  --jobname=JOBNAME     specify a jobname for HPC queue tracking
  --queue=HPC_QUEUE     specify a queue for HPC queue tracking
  --walltime=WALLTIME   specify a walltime for HPC queue tracking
  --email=EMAIL         specify an e-mail adress to warn when HPC job is
                        finished
  --hosts=HOSTS         specify the list of hosts available for parallel mode,
                        ';' delimited
  --ncsize=NCSIZE       the number of processors forced in parallel mode
  --nctile=NCTILE       the number of core per node. ncsize/nctile is the
                        number of compute nodes
  --ncnode=NCNODE       the number of of nodes. ncsize = ncnode*nctile is the
                        total number of compute nodes
  --sequential          if present, imposes that multiple CAS files are
                        launched one after the other
  --mpi                 make sure the mpi command is executed, ignoring any
                        hpc command
  --split               will only do the trace (and the split in parallel) if
                        option there
  --merge               will only do the output copying (and recollection in
                        parallel) if option there
  --run                 will only run the simulation if option there
  --use-link            Will use link instead of copy in the temporary folder
                        (Unix system only)

(base) D:\>
```

  - `telemac2d.bat --help`

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Running TELEMAC (2)

- Open anaconda prompt
- Go to telemac path
  - `cd c:\telemac\v7p2_cookie`
- Apply TELEMAC settings
  - `loadCookie.bat`
- Go to telemac setup directory
  - `cd c:\test\harbour`
- Run TELEMAC
  - `telemac2d.bat -s harbour.cas`
- After running, check the logfile `harbour_....sortie`

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Running in parallel

- Open the harbour.cas file
- Change the keyworks
  - `PARALLEL PROCESSORS = 4`
- Rerun
  - `telemac2d.bat` **`-t`** `harbour.cas`
- Enter the working directory and look for the files
- Now one

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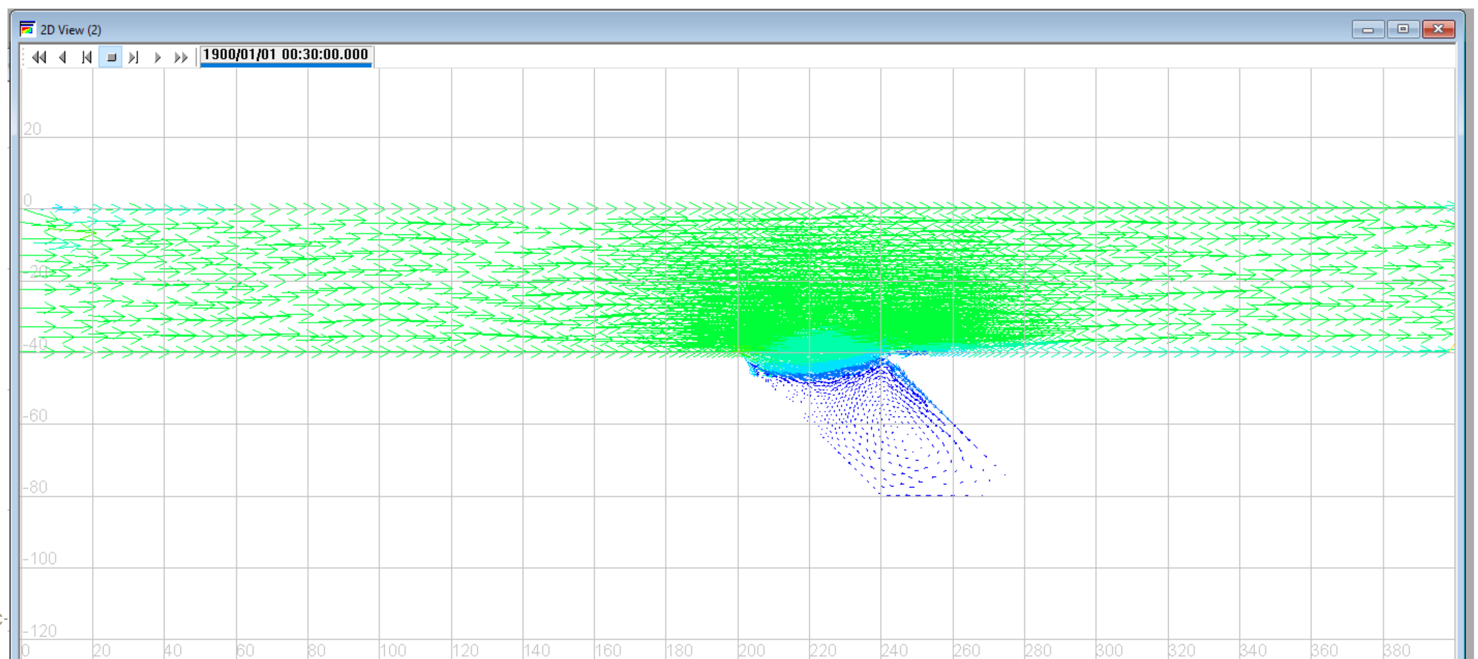
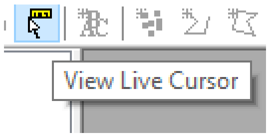
Postprocessing with BlueKenue (1): inspect data

- Open BlueKenue
- Open the results file (Result.slf)
- Drag velocity to 2D view
- ->Right mouse button -> Animate
- Play the animation



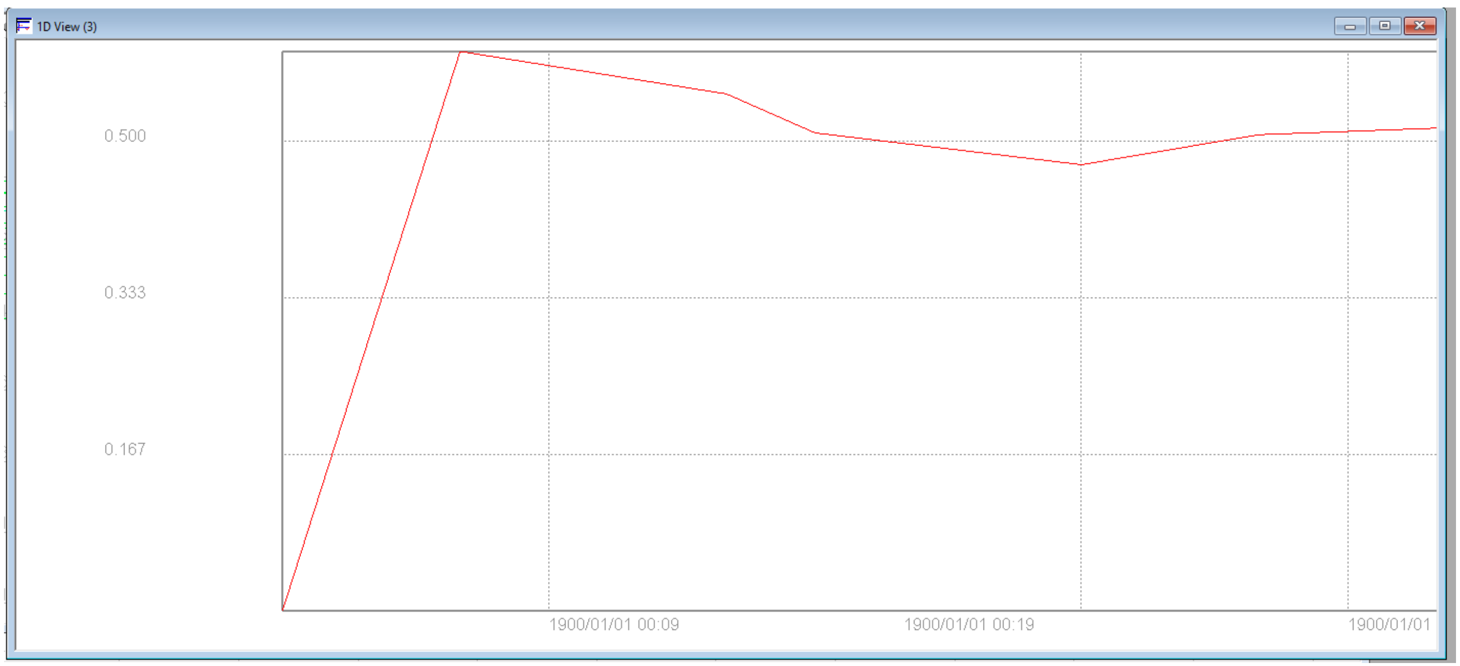
Postprocessing with BlueKenue (2): select properties



- Use live cursor to see streamlines
- Properties of streamlines can be set by selecting 2D view
- Select Velocity and go to properties
  - change visualization (isolines, filled contours)
  - add legend
- Copy and paste display style

Postprocessing with BlueKenue (3): extract time series

- Click on a point
- Right mouse button-> extract time series
- make new 1D view
- Drag time series to 1D view



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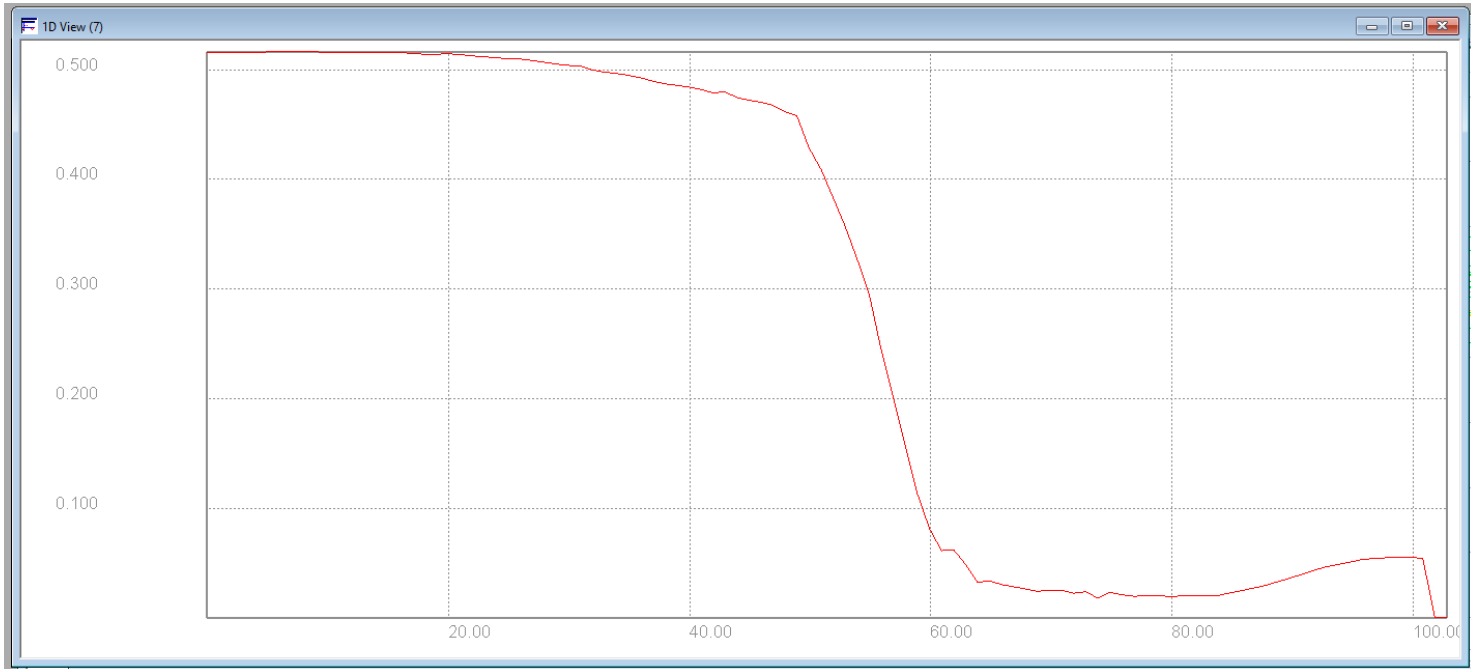
Postprocessing with BlueKenue (4): map to a line

- Make an open line by clicking
- Resample the line
- Tools -> map object -> velocity UV
- drag results to 1D view



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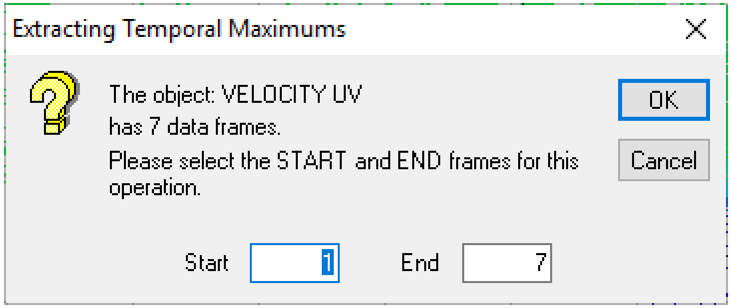
Postprocessing with BlueKenue (1): temporal statistics

- Select velocity
- Tools -> Extract Surface -> Temporal maximum
- Select times
- drag to view



Adding time varying boundary conditions

- Make a liquid boundaries file:

```
T SL(1) Q(2)
s  m     m3/s
0   0.0   0.0
900 0.0 200.0
1800 0.0 200.0
```

- Add keyword LIQUID BOUNDARIES FILE

Lecture 2.3 Preprocessing running TELEMAC (exercise)

Alexander Breugem

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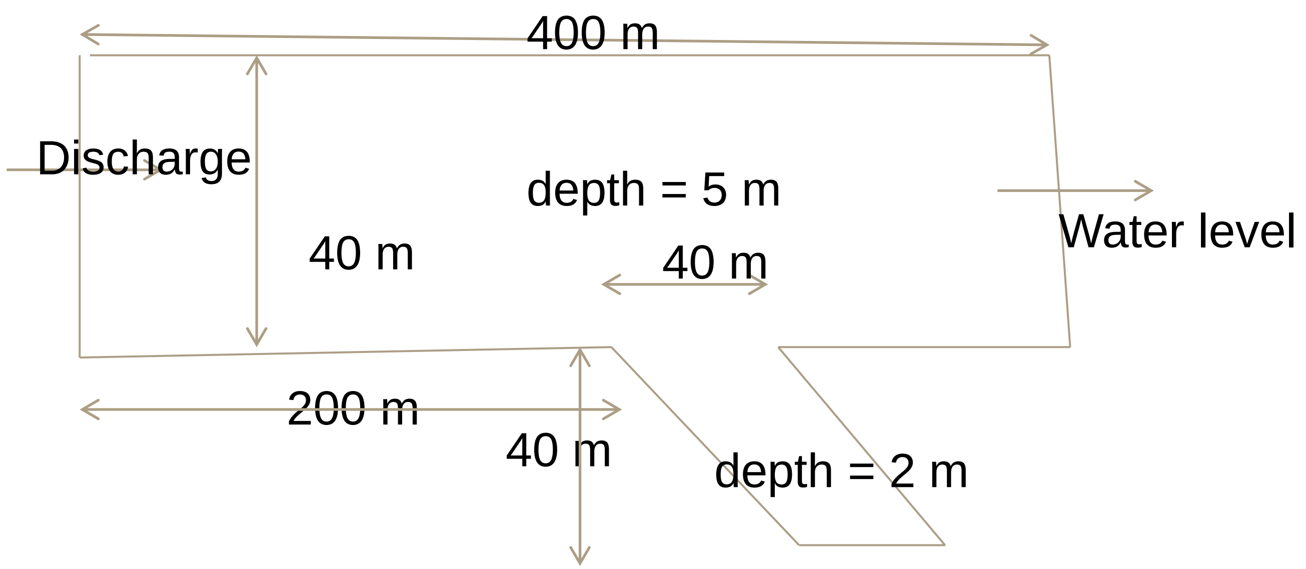
Objective

- Learn to make meshes with BlueKenue
- Lear how to determine boundary conditions
- Learn how to interpolate bathymetry
- Make your first model of a cavity flow
- Run TELEMAC
- See the results



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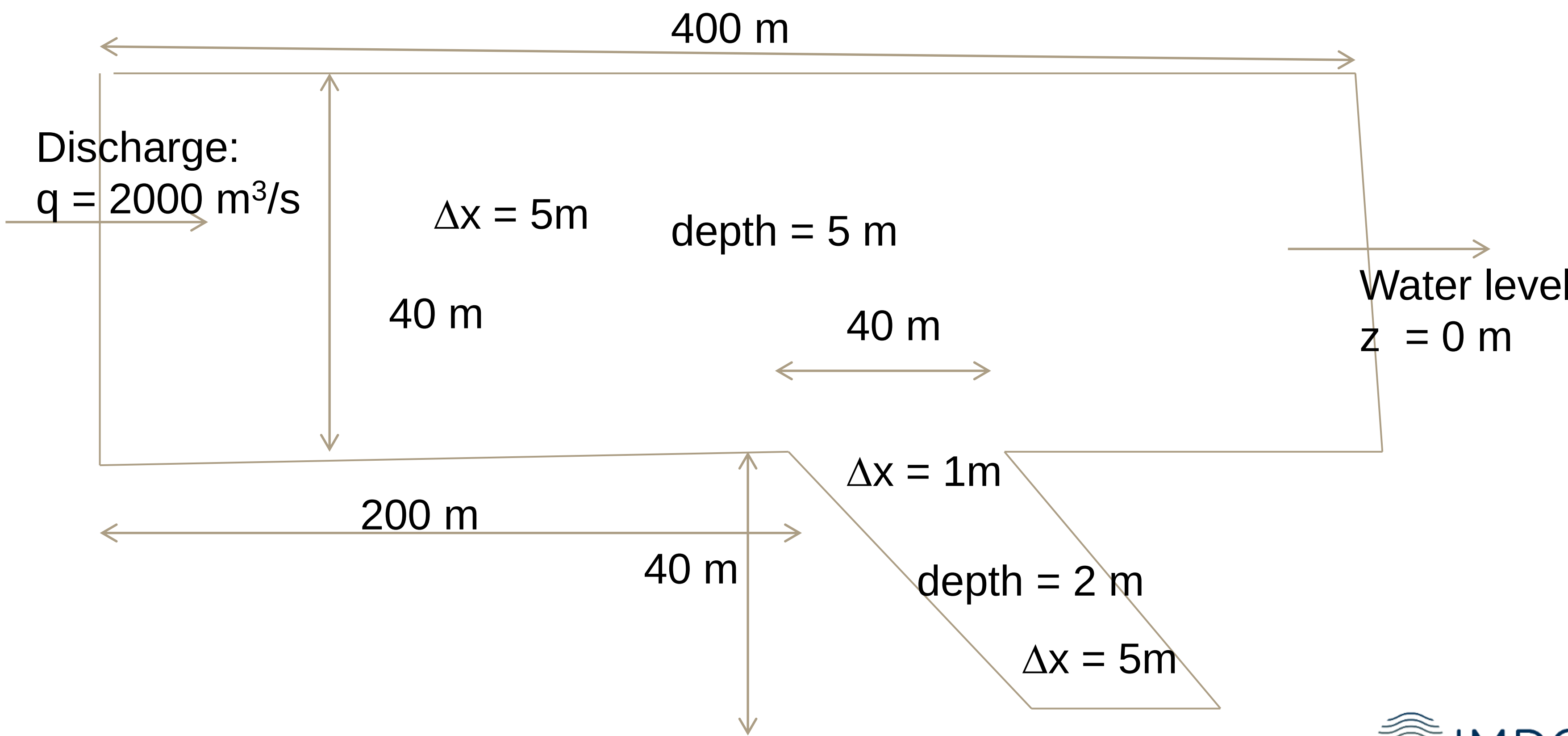
Exercise

Exercise (1)

- Make a grid + cli file for the following situation
- Increase resolution at the harbour entrance!



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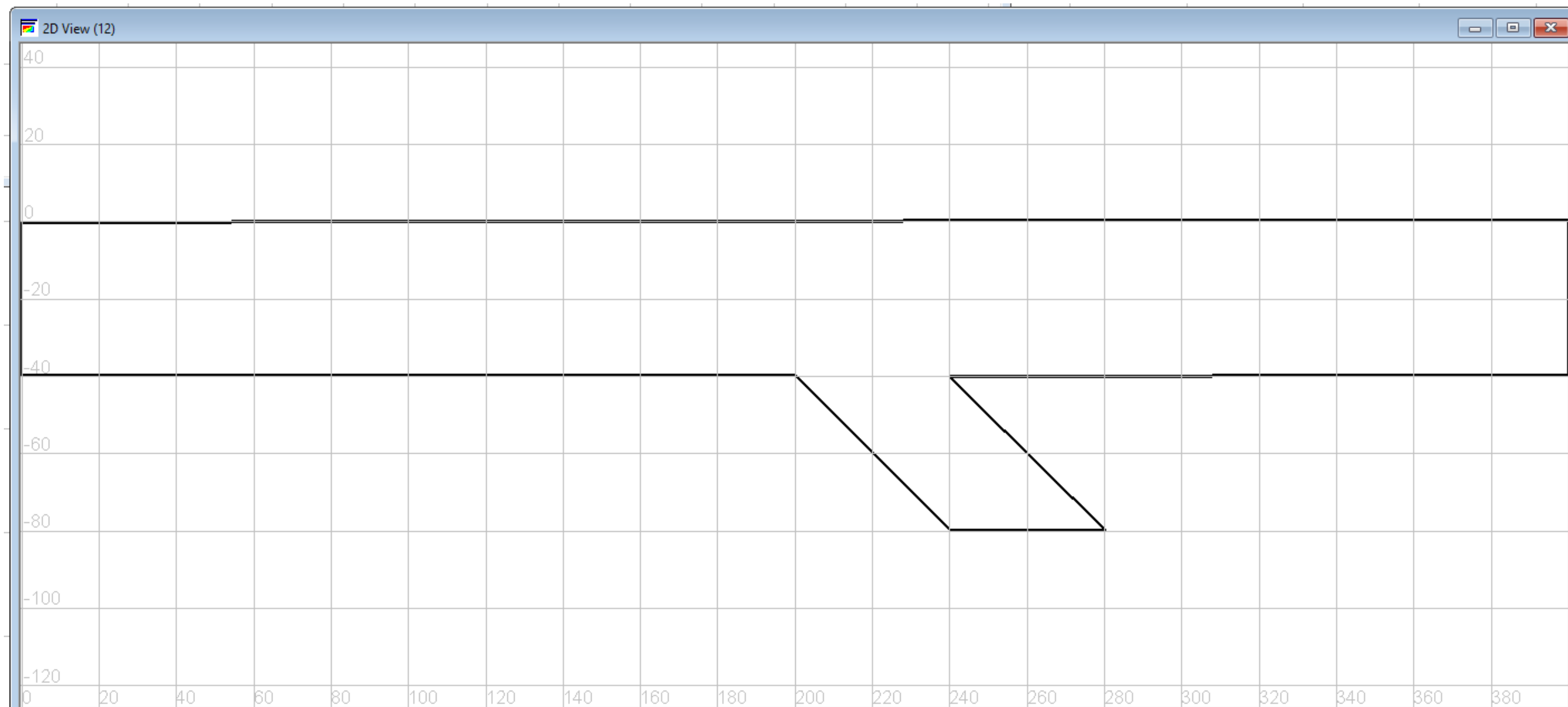
Make an outline:

- Possible options:
  - Click points in BlueKenue
  - Make .i2s file in a text editor



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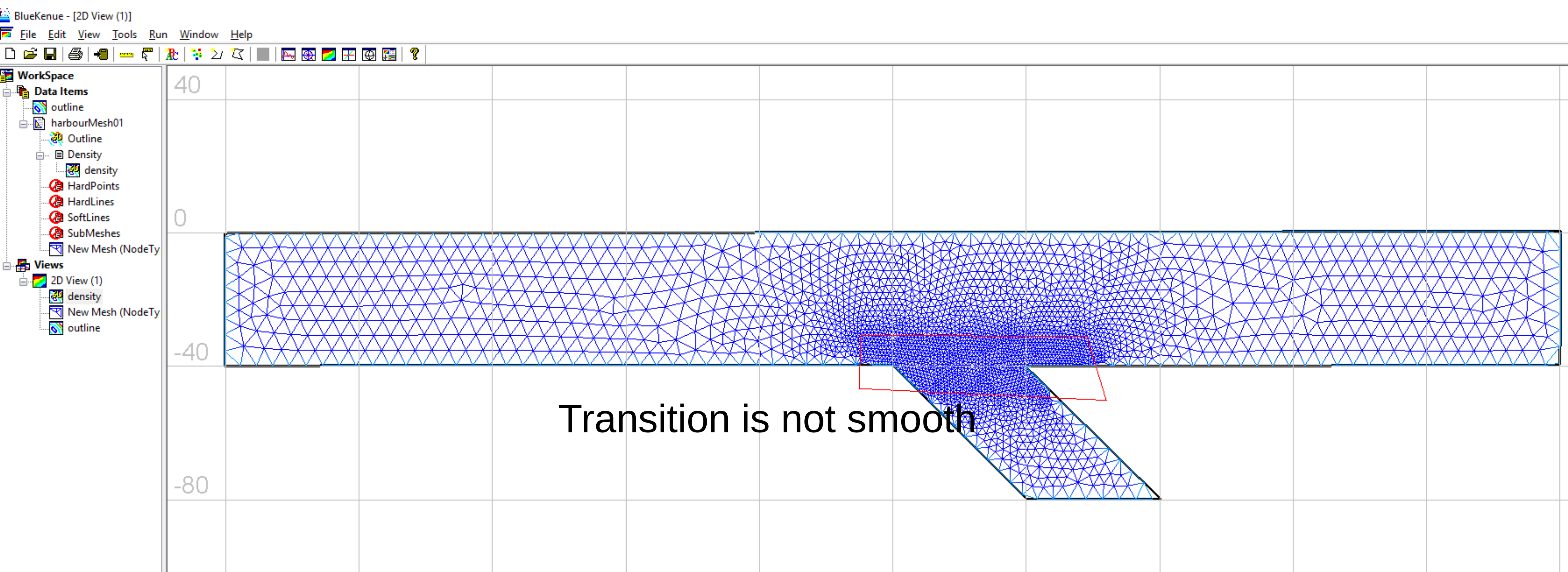
Make a temporary mesh

- Make a mesh generator
- Add outline
- Make a polyline with a higher resolution at the harbor entrance



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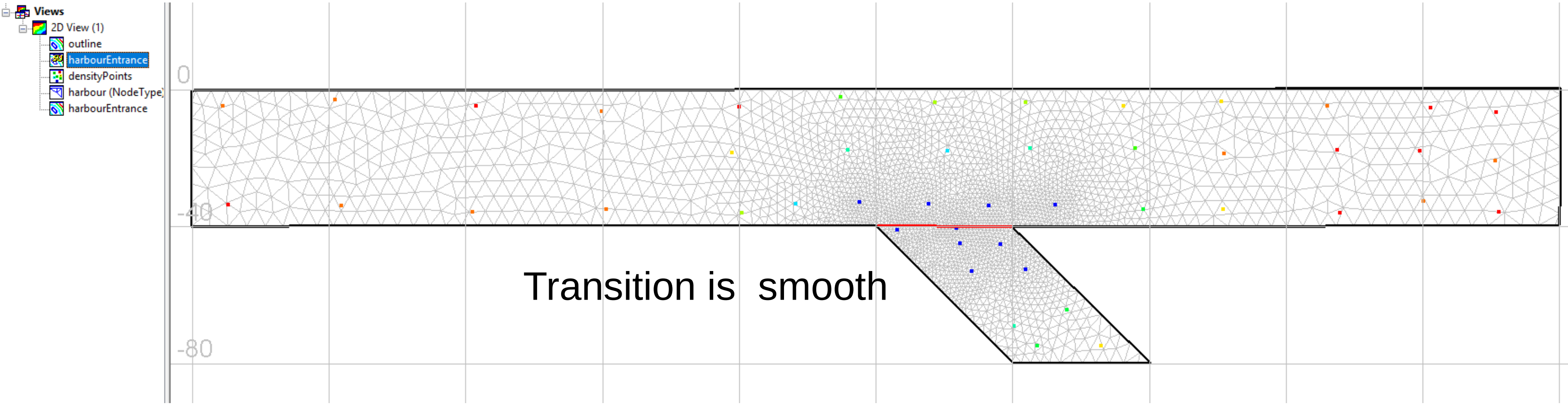
Make the final (smooth) mesh

- Add density points
- Map edge lengths to density points
- Add soft line at the harbor entrance



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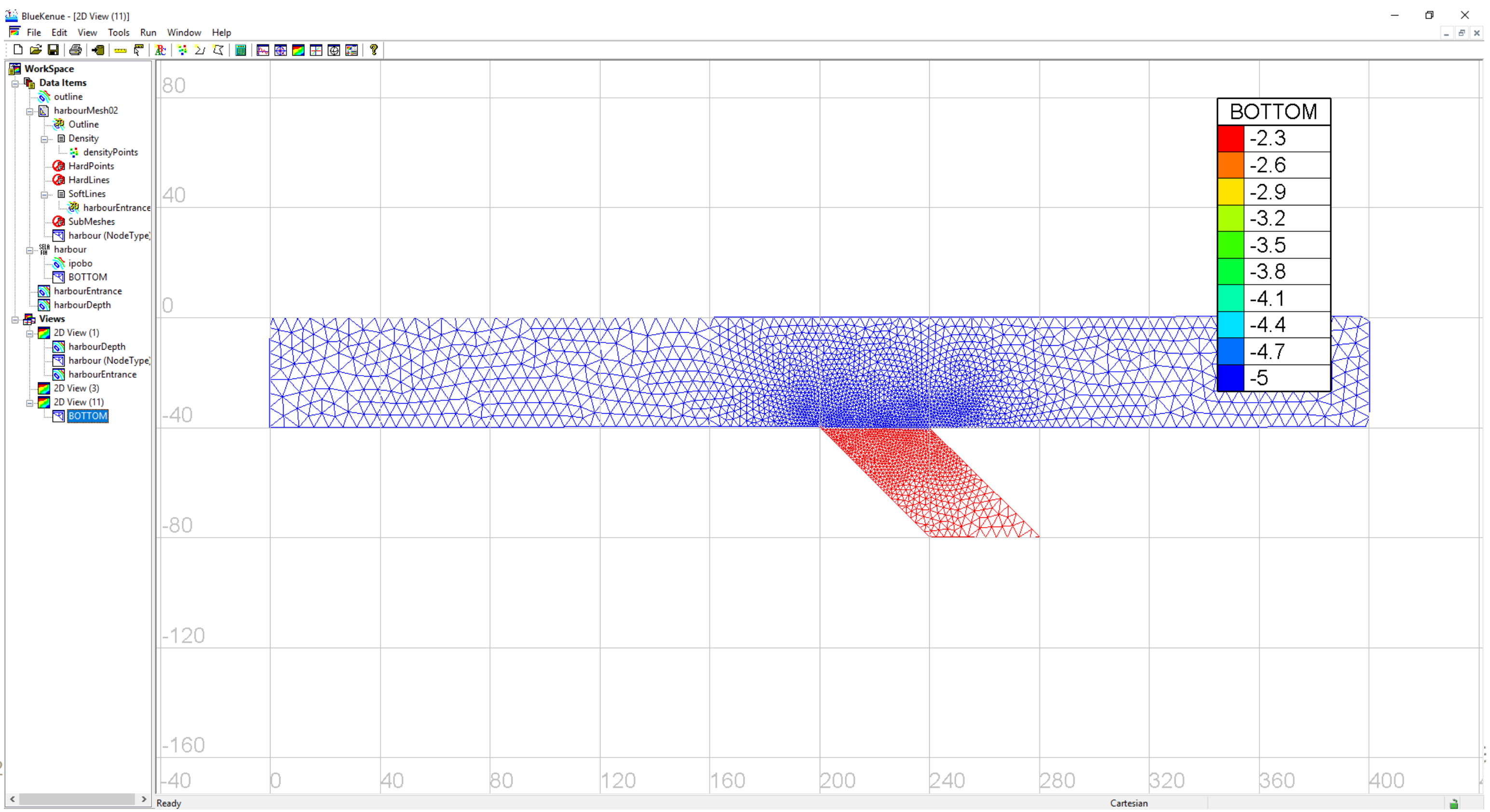
Make a selafin file and add the bathymetry

- Make selafin object
- Add variable BOTTOM with default depth
- Use polyline to set a different depth in the harbor
- Save the .slf file



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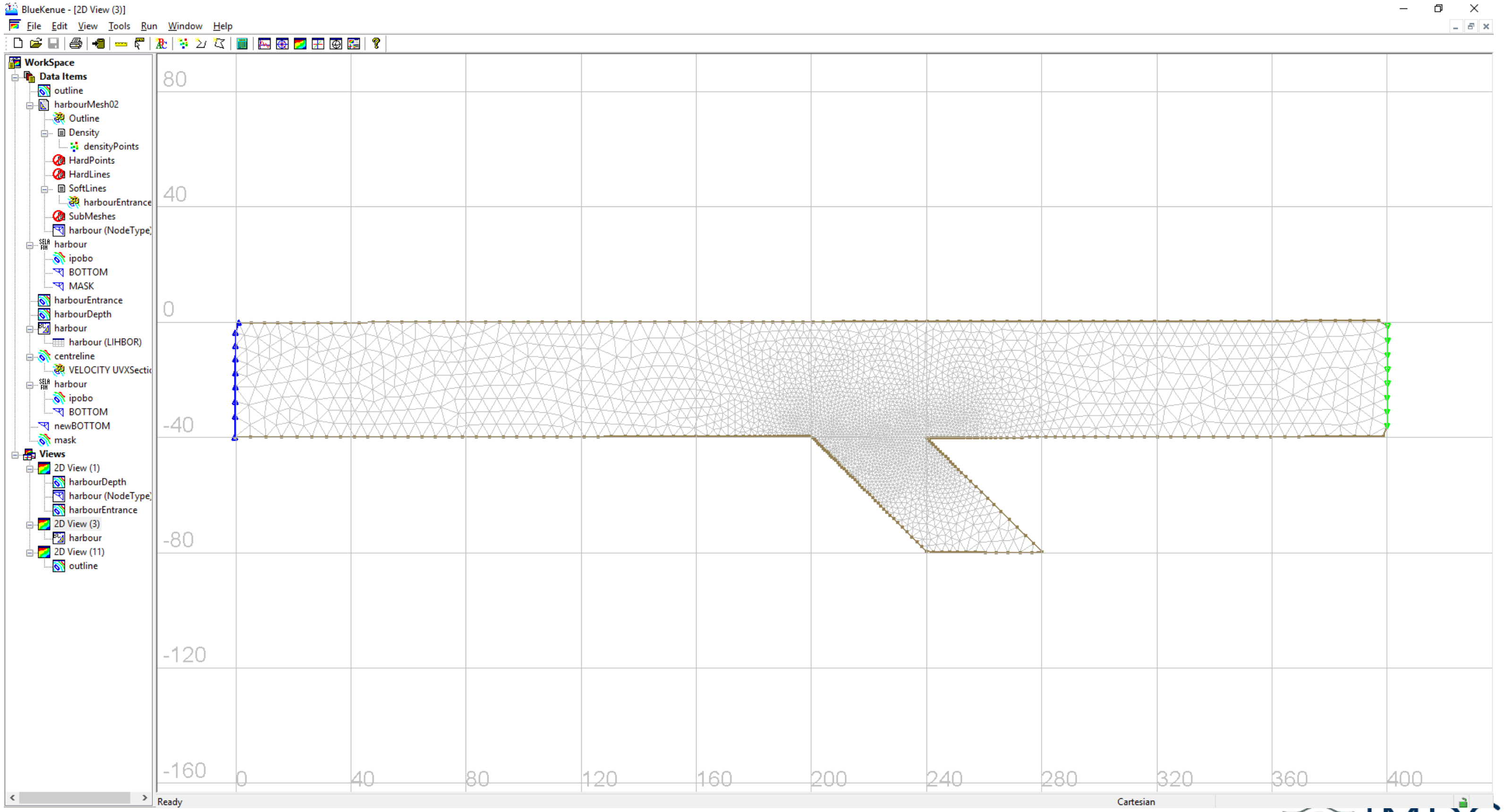
Define boundary conditions:

- New boundary condition object
- Select open boundaries and specify the type
- Save .bc2 file and .cli file



Set up the model

- Copy all input files to run directory
  - .slf file (mesh bathymetry)
  - .cli file (boundary conditions)
  - .cas file (keyword settings)
- Run TELEMAC
  - Open Anaconda prompt and go to working dir
  - `loadCookie.bat`
  - `telemac.bat –s myCas.cas`

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Postprocess

- Open the files in BlueKenue

LECTURE 2.4: Theory of numerical methods modelling

Numerical Modelling of marine processes

- Part 1 – Types of grid discretisations
- Part 2 – Numerical techniques
- Part 3 – Parallellism

Most important message

- **Numerical methods do not solve a differential equation exactly**
  - Different artifacts exist in the solutions

- Objective of the lecture
  - Recognise main artifacts occurring in numerical methods
  - Lear about some remedies against these artifacts

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PART I: TYPES OF GRID DISCRETISATIONS

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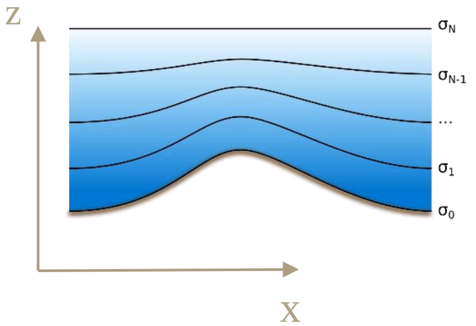
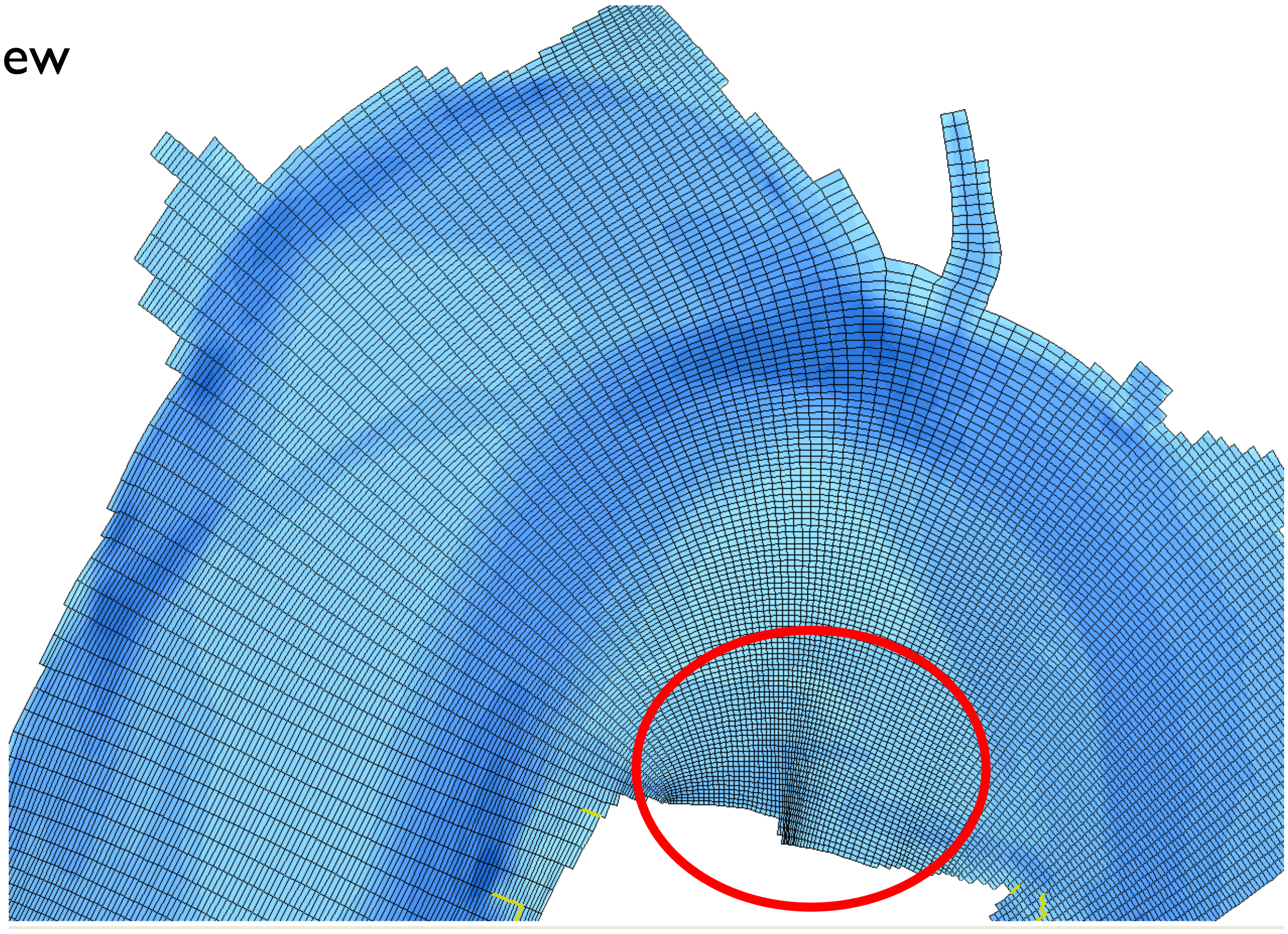
GRID TYPES

- Curvilinear plan view
- Sigma vertical





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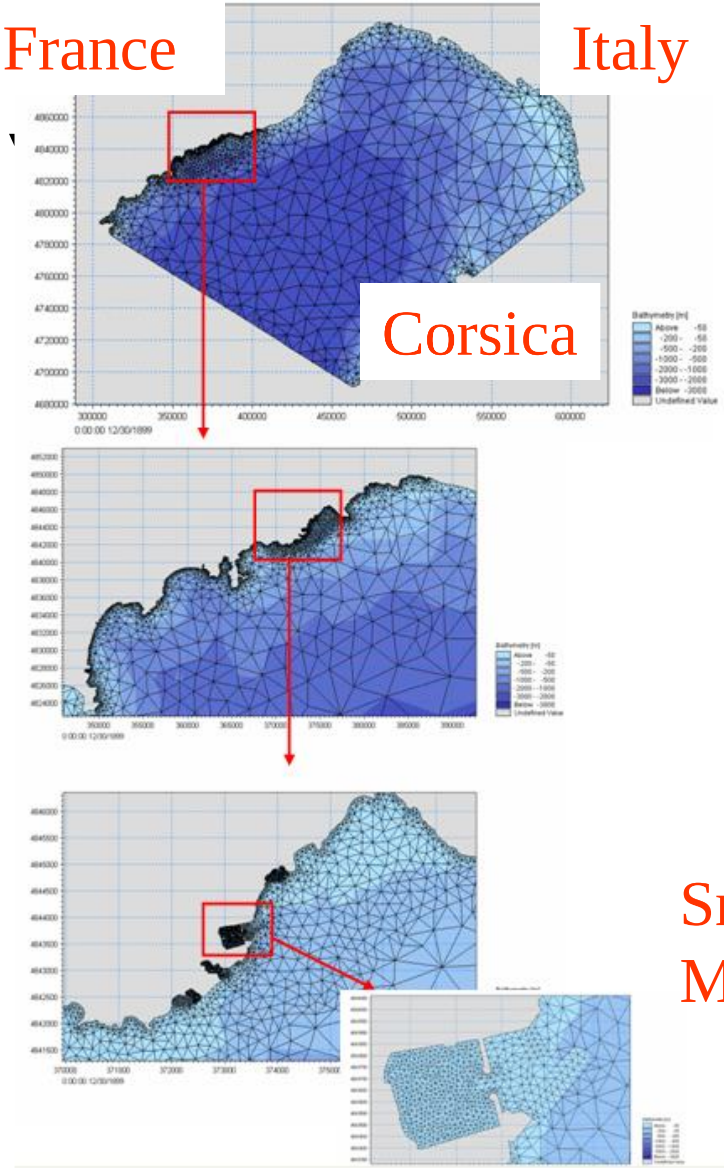
GRID TYPES

- Triangular plan

France

Italy



Ligurian Sea (300km)

Cote d'Azur (50 km)

Monaco Coast (10km)

Small marina in Monaco (1km)

Many different scales in one grid!!

Used by:
RMA,
TELEMAC,
MIKE21FM,
FINEL,…

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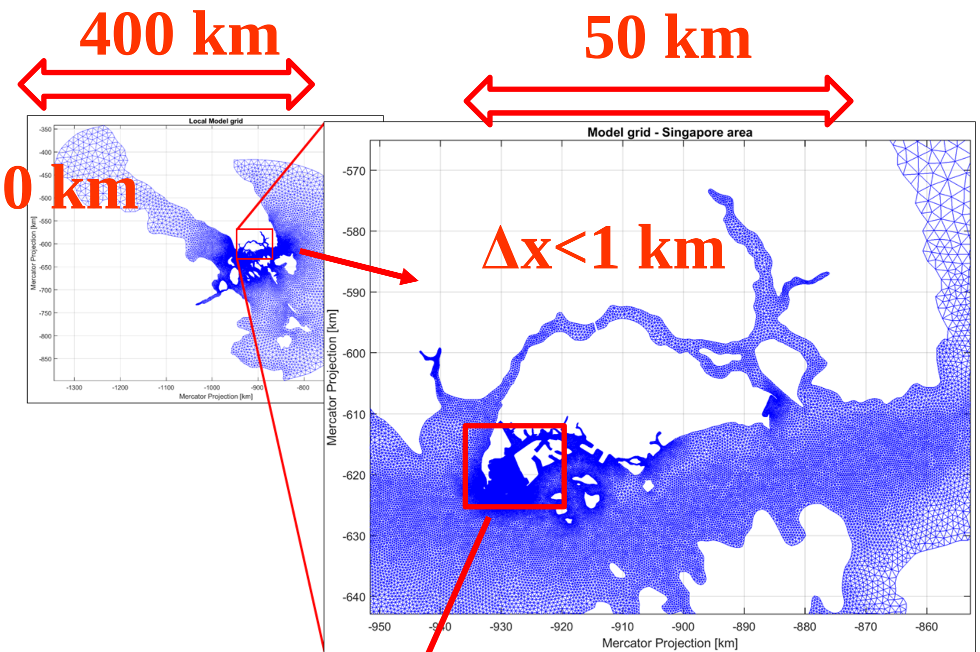
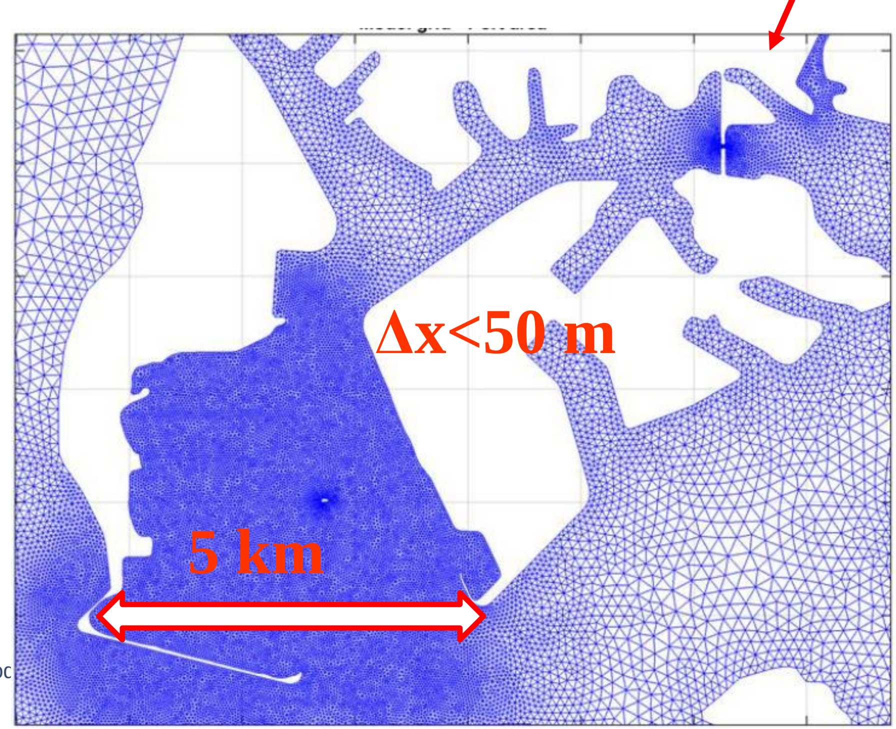
GRID TYPES

- Triangular plan view
- Example model:
  - Extent = 400 km
  - Cell size: 50 m to 10 km





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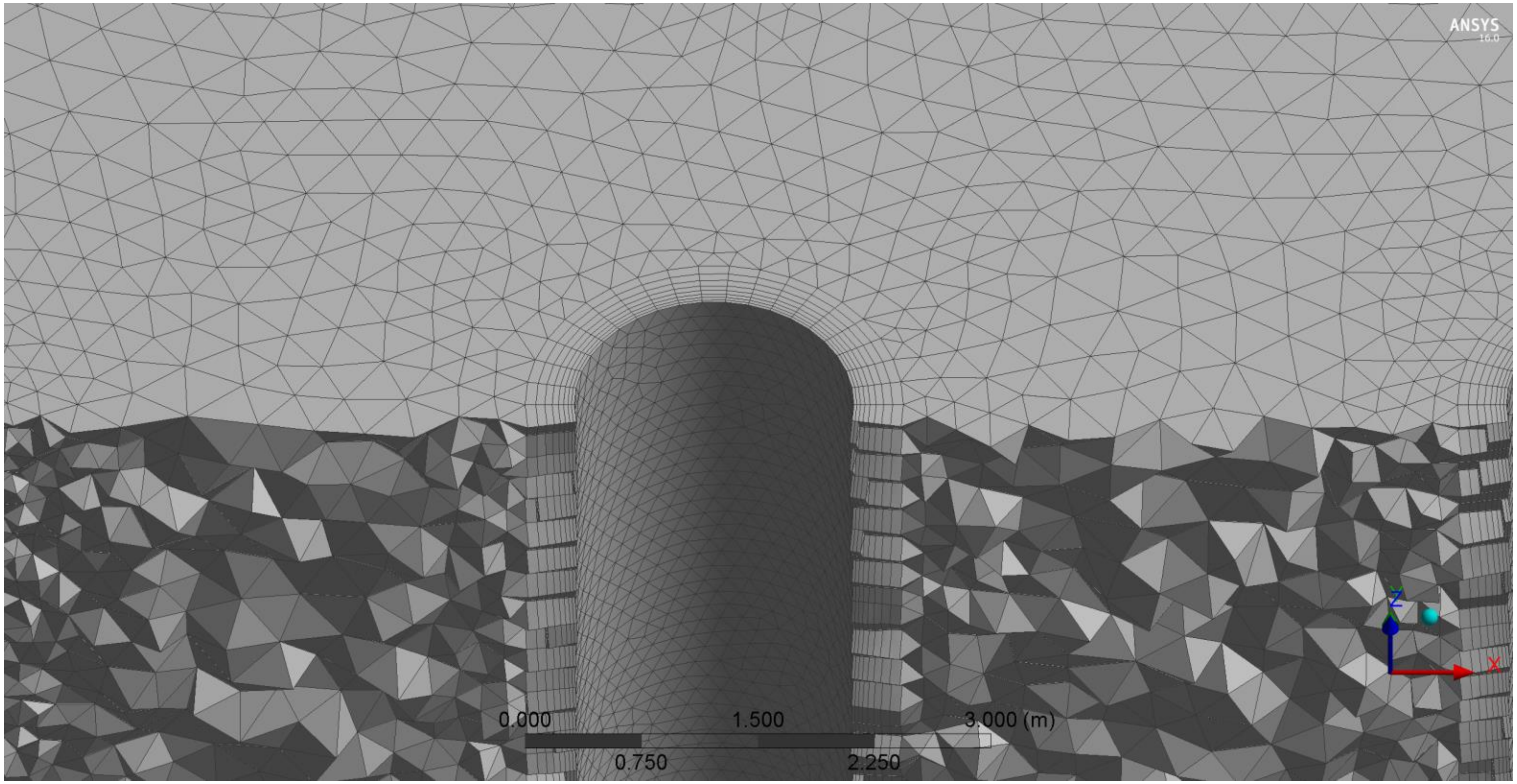
GRID TYPES

- Fully unstructured in 3 dimensions (tetrahedrons, hexahedrons)
- For 3D non-hydrostatic Computational Fluid Dynamics (CFD) models



PART 2: NUMERICAL TECHNIQUES

For the solution of incompressible flow problems

Advection-diffusion equation

- $\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + D\frac{\partial^2 c}{\partial x^2} = 0$
- Model for many other equations (e.g. shallow water equations)
- D = 0 (advection equation)
- $\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} = 0.$
- Solution: propagation block without deformation (for constant u)
- $c(x - ut) = const$

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Characteristics of numerical methods

- Conservation properties
  - Mass conserving
  - Not mass conserving
- Stability
  - Stable
  - Unstable
- Accuracy
  - Truncation error (order of a scheme)
  - Numerical diffusion/Numerical dispersion
- Boundness
  - Wiggle free
  - Wiggles

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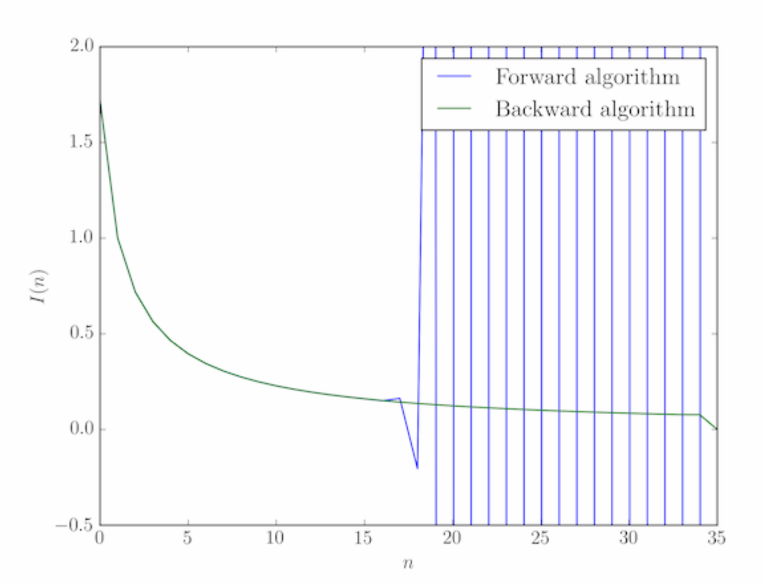
Numerical stability

- Some numerical algorithms may damp out the small fluctuations (errors) in the input data; others might magnify such errors. Calculations that can be proven not to magnify approximation errors are called **numerically stable**.
- Depends on:
  - numerical scheme
  - mesh size
  - time step



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Order of accuracy of scheme

- Tells how fast a scheme convergences to the "true solution" when
- Can be determined using mathematical analysis (Taylor series approach)
- Can be observed experimentally (grid refinement study)
- Example: 2nd order schemes in space, error decreases as $1/\Delta x^2$

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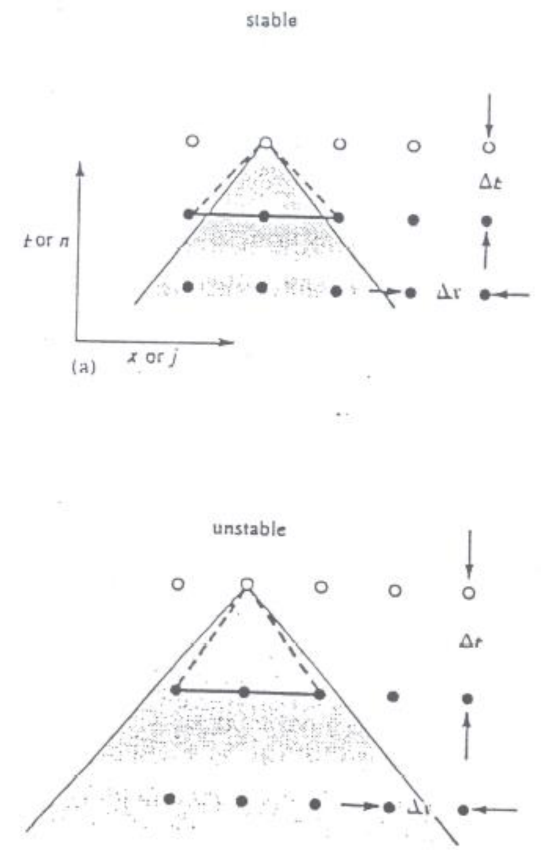
Stability analysis (explicit advection scheme)

- 'Reach' of the solution must cover the speed at which perturbations move in the water (e.g. wave)
- Courant-Friedrich-Lewis condition (CFL):

$$c\frac{\Delta t}{\Delta x} \leq 1$$



Numerical stability example (ordinary differential equation)

- $\frac{dc}{dt} + kc = 0$ (ordinary differential equation; k>0)
- discretize (θ method)
- $c^{n+1} - c^n = -\mathrm{k}\Delta t(\theta c^{n+1} + (1-\theta)c^n)$
- This gives
- $c^{n+1} = c^n\left(\frac{1}{1+k\Delta t}\right)$ (θ=1; fully implicit)
- $c^{n+1} = c^n(1 - k\Delta t)$ (θ=0; fully eplicit)
- What happens if Δt is large?

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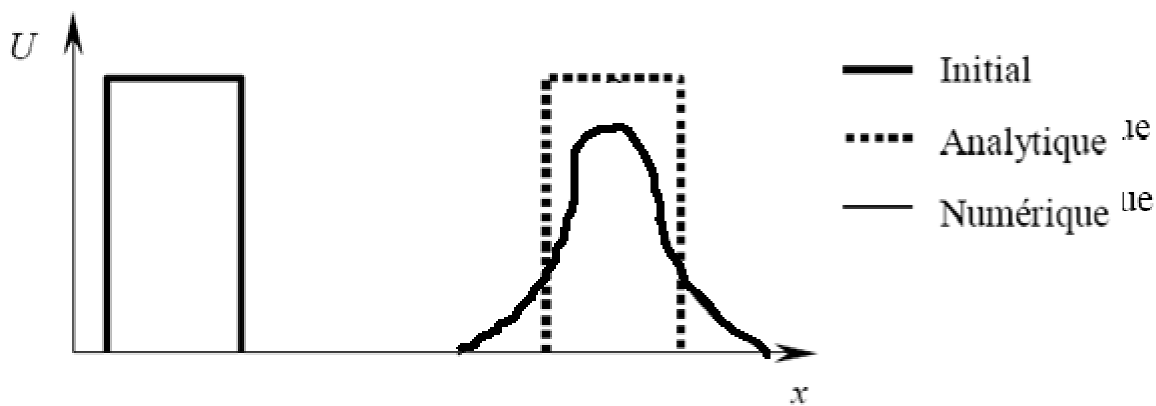
Numerical stability (conclusion)

- Implicit schemes: stability does not depend on time step
- Explicit schemes: stability depends on time step
  - Typically, there is a CFL criterion
- For partial differential equations:
  - Implicit schemes lead to matrix equations to be solved;
  - Therefore implicit schemes are more difficult to implement than explicit schemes
  - Large calculation time (per time step) for implicit timestep, but..
  - Larger time steps are possible

Numerical diffusion

- Scheme property (especially for first order schemes)
- Solution gets smoothed out
- Peak decreases;
- No new extrema are being formed



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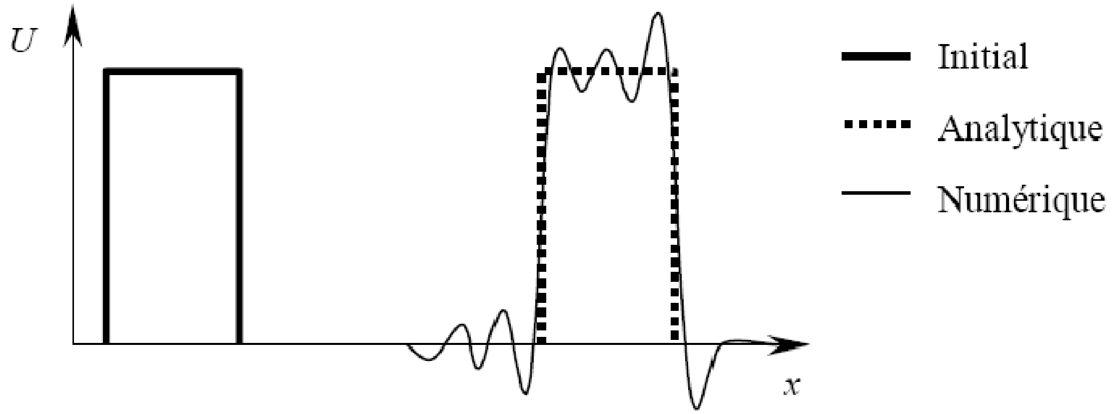
Boundness/numerical dispersion

- Scheme property
- Typical for high order schemes
- New extrema are formed
- Data may advect at a different speed



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Godunov order barrier theorem

- **Linear** numerical schemes for solving partial differential equations (PDE's), having the property of not generating new extrema (monotone scheme), can be at most **first-order accurate**.
- Hence non-linear schemes are needed
- Typical solution, flux limiters:
  - Use second order schemes at smooth parts
  - Use first order schemes near discontinuities

Time discretization: fractional step method

- Time discretization in various sub steps
- $\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + D\frac{\partial^2 c}{\partial x^2} = 0$
- Step 1: advection terms
- $\tilde{c} = c^n + \Delta t\ ADV$
- Step 2: diffusion and sources (implicit)
- $c^{n+1} = c^n + \Delta T(\theta\ DIFF(c^{n+1}) + (1-\theta)DIFF(\tilde{c})$

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Different numerical methods for space discretisation

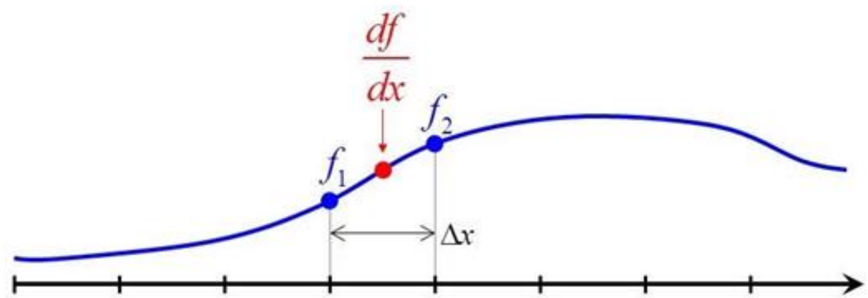
- Finite differences
  - Easy to implement/understand
  - Only possible on structured meshes
- Finite volume
  - Relatively easy to implement/understand
  - Can be extended to unstructured meshes
- Finite element
  - Naturally on unstructured meshes
  - Leads to system of linear equations (matrices)
  - Easy to extend to high orders of accuracy

Finite difference method

- Discretisation based directly on differential equation

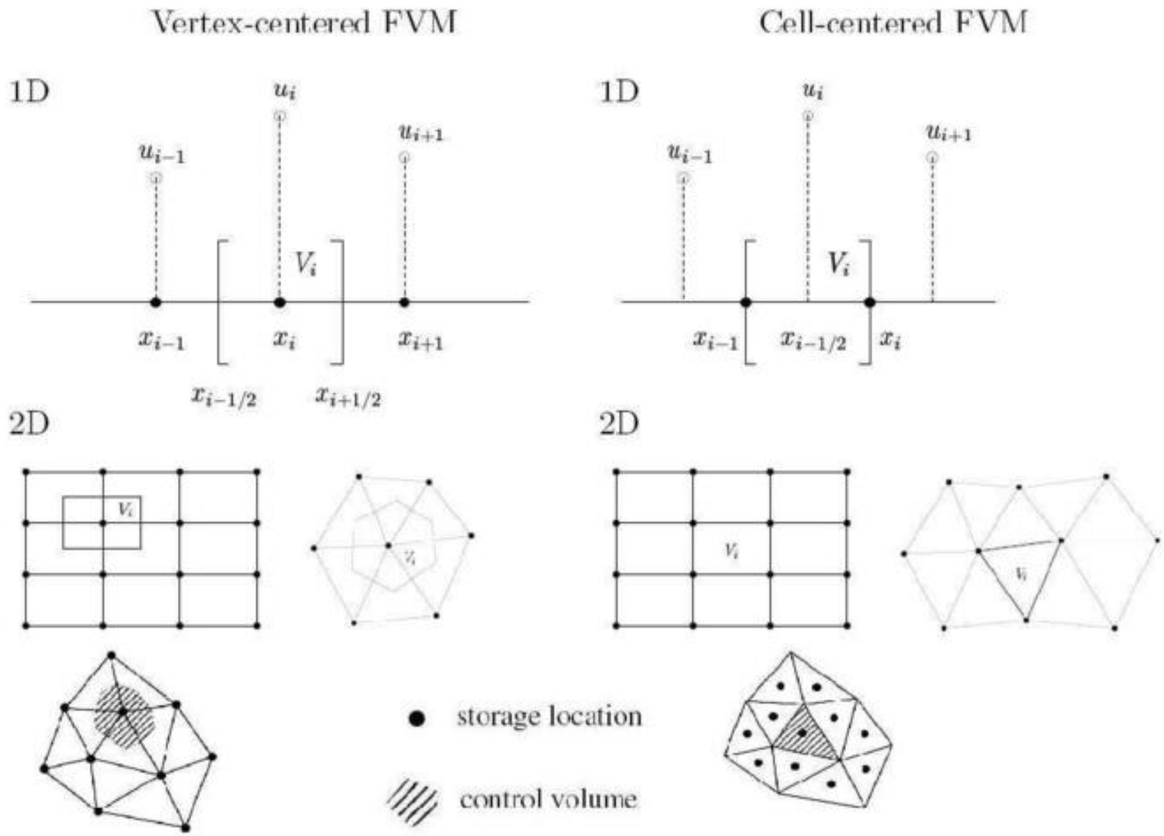
$$\frac{df_{1.5}}{dx} \approx \frac{f_2 - f_1}{\Delta x}$$

second-order accurate
first-order derivative



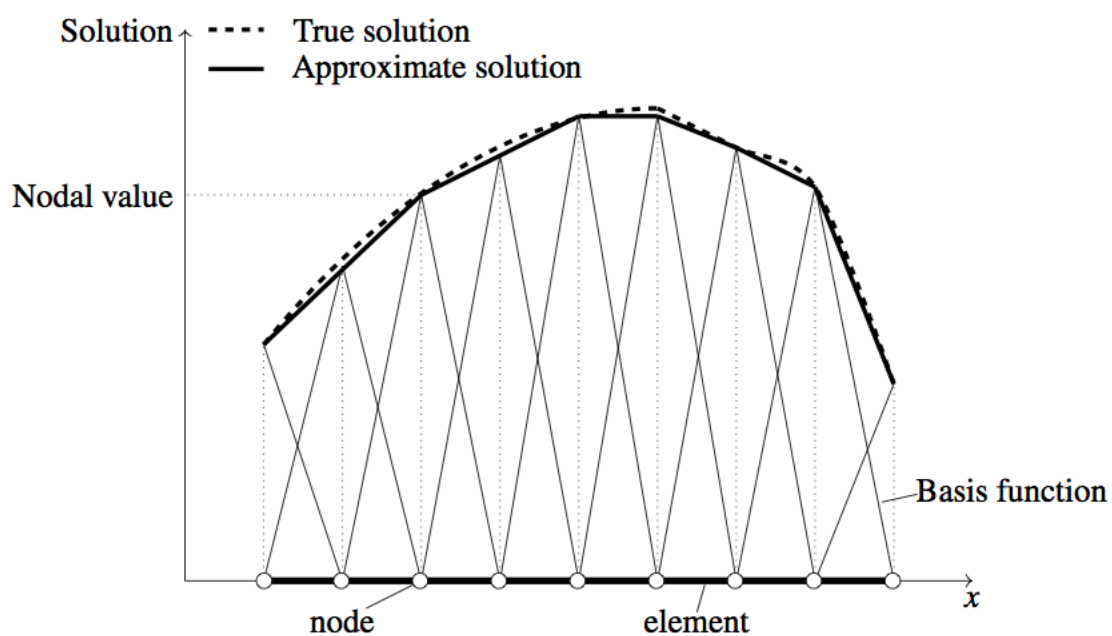
Finite volume method

- Physical based method (control volumes and fluxes)



Finite element method

- Discretisation based on combination of base functions
- Rather mathematical technique
- Behaviour between nodes is defined



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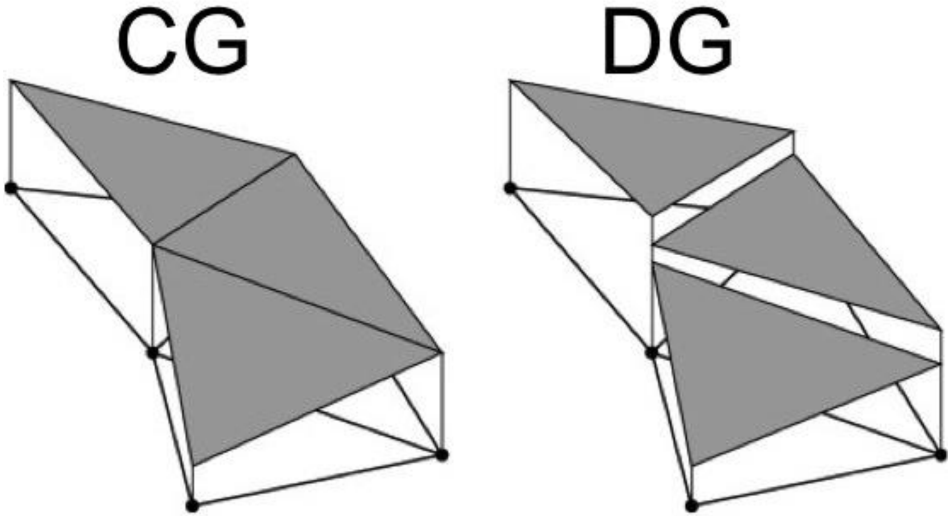
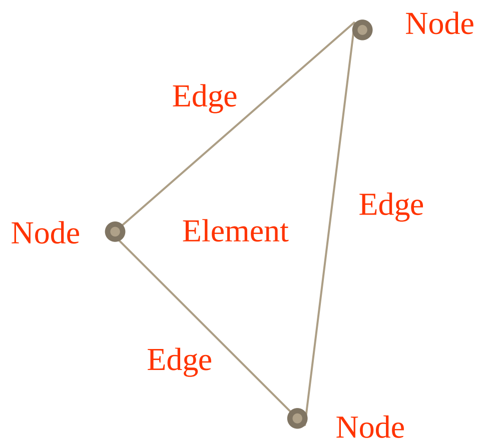
Finite element method

- Continuous Galerkin
- Discontinuous Galerkin



Finite element terminology

- Node: point
- Edge: connection between two points
- Element: triangle



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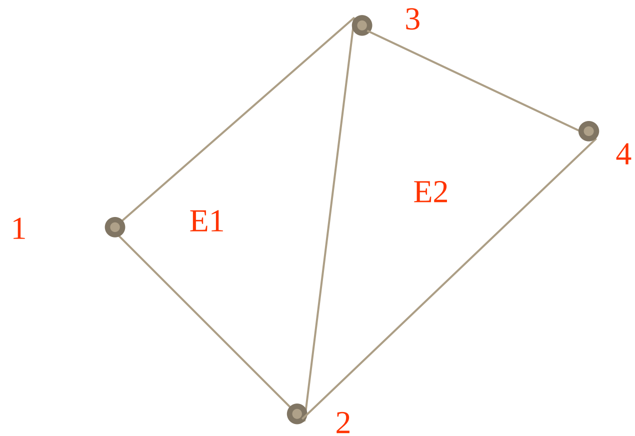
Finite element data structure

- Coordinate table (XYZ)
- Element connectivity table (IKLE)
- Data table (RESULT)
- Special tables for boundaries

XYZ
[0 0.5 0
0.5 0.0 0
0.6 1.0 0
1.0 0.6 0]



IKLE:
[1 2 3
2 4 3]

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Finite element derivation (1): weak form

- Rewrite the equations as a variation problem:
  - Multiply with test function and integrate
- Example for diffusion equation:

$$\int_\Omega \boldsymbol{u}^D \cdot \boldsymbol{\Psi}_i \, d\Omega - \delta t \, \theta_d \int_\Omega \nabla \cdot (\nu_E \boldsymbol{\nabla} \boldsymbol{u}^D) \cdot \boldsymbol{\Psi}_i \, d\Omega = \int_\Omega \boldsymbol{u}^A \cdot \boldsymbol{\Psi}_i \, d\Omega$$

$$+ \delta t (1 - \theta_d) \int_\Omega \nabla \cdot (\nu_E \boldsymbol{\nabla} \boldsymbol{u}^A) \cdot \boldsymbol{\Psi}_i \, d\Omega$$

- Use integration by parts and Gauss Theorem to get:

$$\int_\Omega \nabla \cdot (\nu_E \boldsymbol{\nabla} \boldsymbol{u}^D) \cdot \boldsymbol{\Psi}_i \, d\Omega = \int_\Omega \nabla \cdot (\nu_E \boldsymbol{\nabla} \boldsymbol{u}^D \cdot \boldsymbol{\Psi}_i) \, d\Omega - \int_\Omega \nu_E \boldsymbol{\nabla} \boldsymbol{\Psi}_i : \boldsymbol{\nabla} \boldsymbol{u}^D \, d\Omega$$

$$= \int_\Gamma \nu_E \boldsymbol{\nabla} \boldsymbol{u}^D \cdot \boldsymbol{\Psi}_i \cdot \boldsymbol{n} \, d\Gamma - \int_\Omega \nu_E \boldsymbol{\nabla} \boldsymbol{\Psi}_i : \boldsymbol{\nabla} \boldsymbol{u}^D \, d\Omega$$

Finite element derivation (2): projection to base functions

- Substitute

$$u_h = \sum_{i=1}^{n} u_i \Psi_i$$

$$\nabla \boldsymbol{u}^D = \sum_j \boldsymbol{u}_j^D \nabla \boldsymbol{\Psi}_j$$

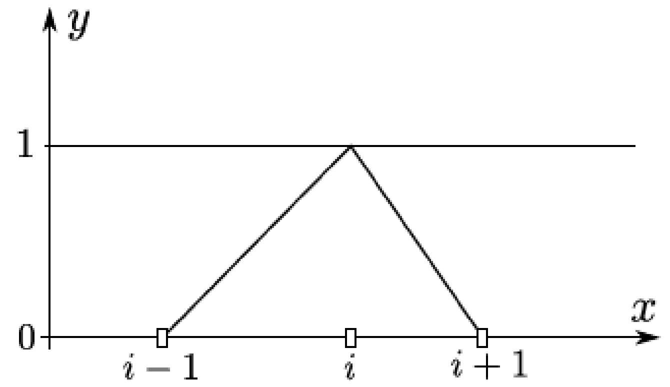

Figure 2.1: Shape of a linear basis in one dimension.

- This gives a matrix equation:

Mass matrix

Diffusion matrix

Mass matrix

$$\boldsymbol{u}_j^D \int_\Omega \boldsymbol{\Psi}_i \cdot \boldsymbol{\Psi}_j \, d\Omega + \delta t \, \theta_d \nu_{Ej} \boldsymbol{u}_j^D \int_\Omega \nabla \boldsymbol{\Psi}_i : \nabla \boldsymbol{\Psi}_j \, d\Omega - \boldsymbol{u}_j^D \int_\Gamma \nu_E \nabla \boldsymbol{\Psi}_j \cdot \boldsymbol{\Psi}_i \cdot \boldsymbol{n} \, d\Gamma = \boldsymbol{u}_j^A \int_\Omega \boldsymbol{\Psi}_i \cdot \boldsymbol{\Psi}_j \, d\Omega$$

$$+ \delta t (1 - \theta_d) \nu_{Ej} \boldsymbol{u}_j^A \int_\Omega \nabla \boldsymbol{\Psi}_i : \nabla \boldsymbol{\Psi}_j \, d\Omega \qquad (4.13)$$

Diffusion matrix

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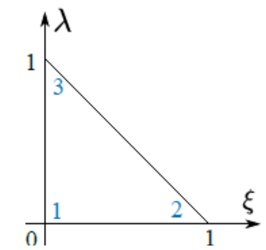
Finite elements (3)

- Determination of the element matrices
  - Analytical integration (linear functions)
  - Numerical integration (gauss method)



$$x = (1-\alpha-\beta)x_1 + \alpha x_2 + \beta x_3$$
$$y = (1-\alpha-\beta)y_1 + \alpha y_2 + \beta y_3$$

$$|\boldsymbol{J}| \;= \frac{1}{2}[(x_2-x_1)(y_3-y_1)+(x_1-x_3)(y_2-y_1)]$$

$$\Psi_i(x,y,z) = \Phi_i(F^{-1}(x,y,z))$$

$$\Phi_1 = (1-\xi-\lambda)\Phi_2 = \xi\Phi_3 = \lambda$$

Finite elements (5)

- Consequence of finite element method:
  - Value at a node is the sum of all surrounding element functions
  - A node influences all surrounding elements

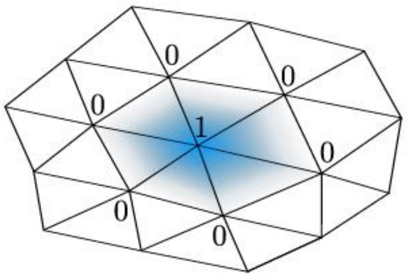


Figure 2.2: Extent of a basis function on a triangular mesh. The blue color represents higher values of the basis function.

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Finite element (4): inf-sup condition

- In finite elements, some functions are "invisble"
- Extra techniques are needed to stabilize the wiggles

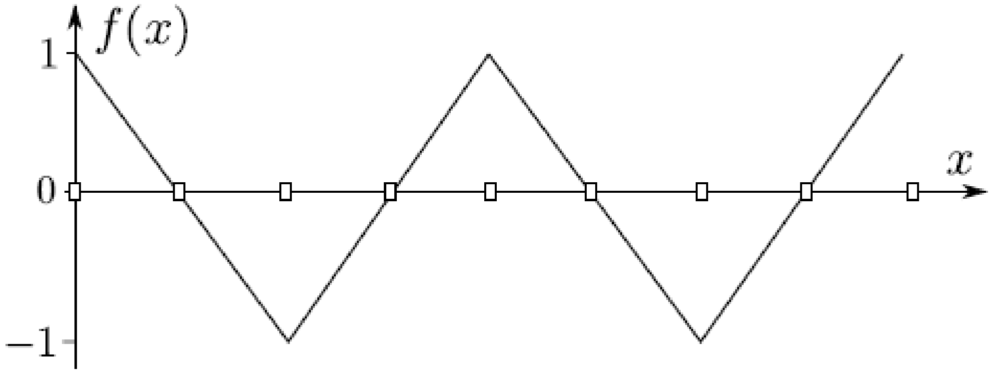
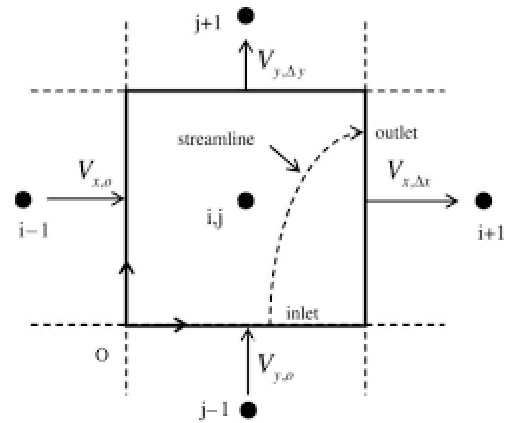


Figure 2.5: An example of invisible function for the gradient operator.

Advection schemes finite element method

Characteristic method (Lagrangian method)

- Algorithm:
  - Calculate a streamline back in time
  - Interpolate
- Stable (no time step criterion)
- Fast
- Relatively limited numerical diffusion
- Not conservative (do not use for tracers)



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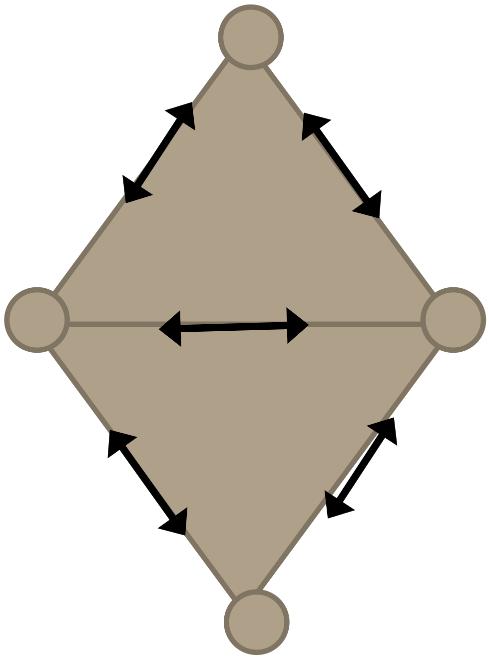
SUPG schemes

- Idea:
  - Deform shape function in streamwise direction
  - Discretize finite element equations
  - Advection matrix is added to diffusion matrix (no fractional step)
- Consequence
  - Adding diffusion in streamwise directions (but not in cross stream direction

Residual distribution schemes

- Fluxes are transported along edges (between nodes)
- Time step internally chosen (based on stability/maximum criterion)
- Bounded
- Stable
- Conservative
- Diffusive
- Examples:
  - N-scheme
  - Psi-scheme



Advection schemes (within finite element method)

- Overview of advection schemes in TELEMAC

Scheme	Conservation	Max. principle	Tidal flats	Order	Num. diffusion
Characteristics	No	Yes	Yes	1	−
Weak characteristics	No	No	Yes	1	−−
SUPG	No	No	No	1	+
Classical N or PSI	Yes	Yes	No	1	++
1st order pred/corr N or PSI	Yes	Yes	No	1	−−
2nd order pred/corr N or PSI	Yes	Yes	No	2	−−
Leo Postma wo/ tidal flats	Yes	Yes	No	1	++
Leo Postma w/ tidal flats	Yes	Yes	Yes	1	++
NERD	Yes	Yes	Yes	1	++
LIPS N or PSI	Yes	Yes	Yes	1	−−

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Live demo advection schemes

- Test of propagation of
  - Using different advection schemes
    - Characteristics
    - NERD
    - LIPS

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Solutions of matrices

- Discretization using finite element leads to a matrix equation
- $A\vec{x} = \vec{b}$
- Characteristics of the matrices
  - Large (NxN), with N number of points
  - Sparse (most elements are zero)
- How to solve them as fast as possible

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Matrix solution methods

- Direct method
  - Scales as $O(N^3)$: very slow for large matrices
  - Exception, tridiagonal matrices O(N)
- Iterative method:
  - Iterate until a required accuracy is reached; not a full solution
  - Number of iterations depends on required accuracy
  - Examples: conjugate gradient (symmetric matrices), GMRES (any matrix)
- Multigrid method
  - Solve equation on appropriate resolute (long waves on coarse mesh, short waves on fine mesh)
  - Scales as O(N); fastest method available

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PART 3:
Parallellism

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Parallellism

- Parallel computations decrease calculation time
- Parallel computations can be used to run larger models than possible on a pc

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Kind of parallelism (1)

- Shared memory (OpenMP)
  - Simultaneous calculation on different processors
  - Data remains together
  - Easy to program
  - Limited to single computer/node (limited maximum number of processors)
- Distributed memory (MPI)
  - Simultaneous calculation on different processors
  - Each processor has its own memory
  - Can be used on many computers (large amount of processors)
  - Exchange of information between processes need to be programmed explicitly
  - Difficult to program, debug (race conditions)
- Shared and distributed memory can be combined

Kind of parallelism (2)

- Embarrassingly parallel problems
  - No exchange of information needed
  - Very fast in parallel
  - Very easy to perform

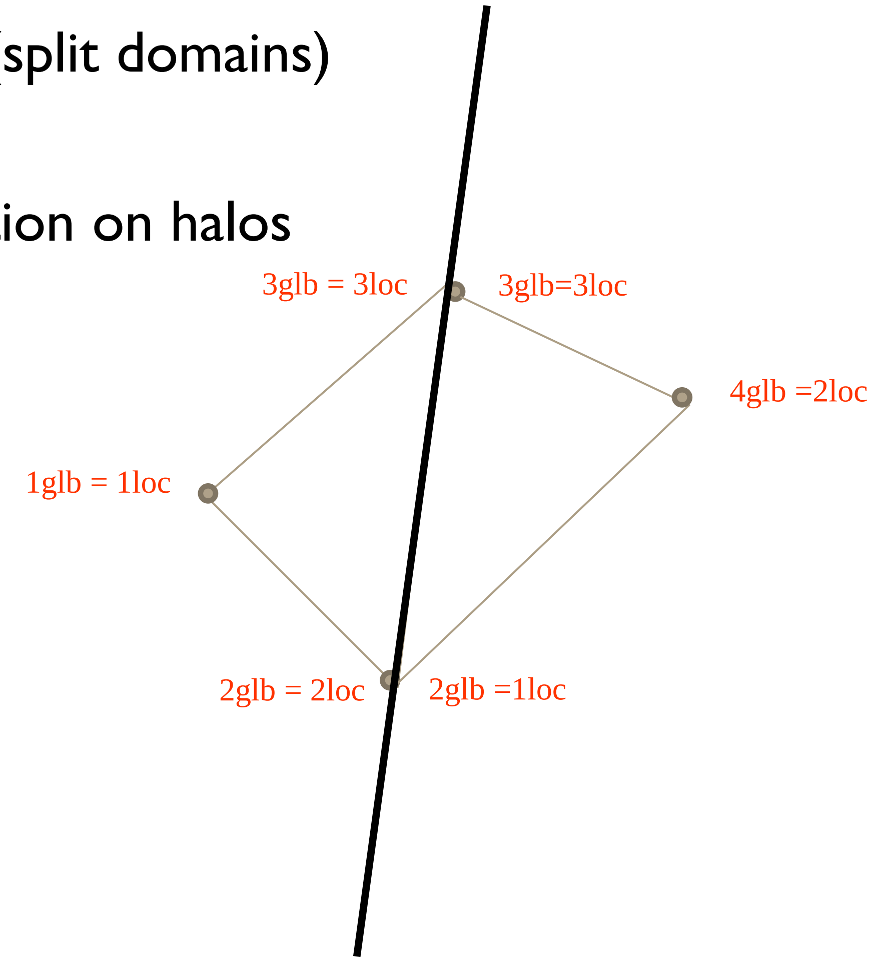
- GPU computing
  - Very large parallelism (GPU consist of many simple processors)
  - Special language needed (CUDA, OpenCL), only works in C.
  - Bottle neck is exchanging information between CPU and GPU.

IMDC

Distributed memory computations

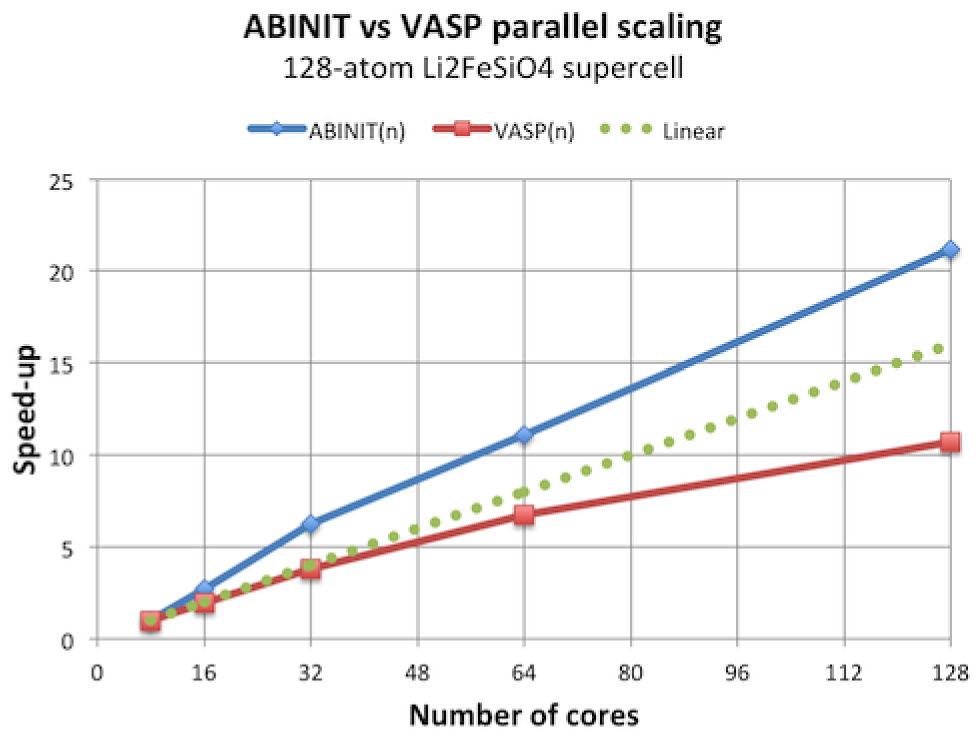
- Perform domain decomposition (split domains)
- Calculate on each processor
- When needed exchange information on halos

- Note:
  - What about input/output
  - Two numberings for each node
    - local
    - global



Parallel computation: scaling

- Scaling: increase in speed with more processors
- Is linear for a certain range
- Use to determine optimum number of processes
- Optimum number of processors depends on the problem (ratio of number of calculations versus amount of data exchange)



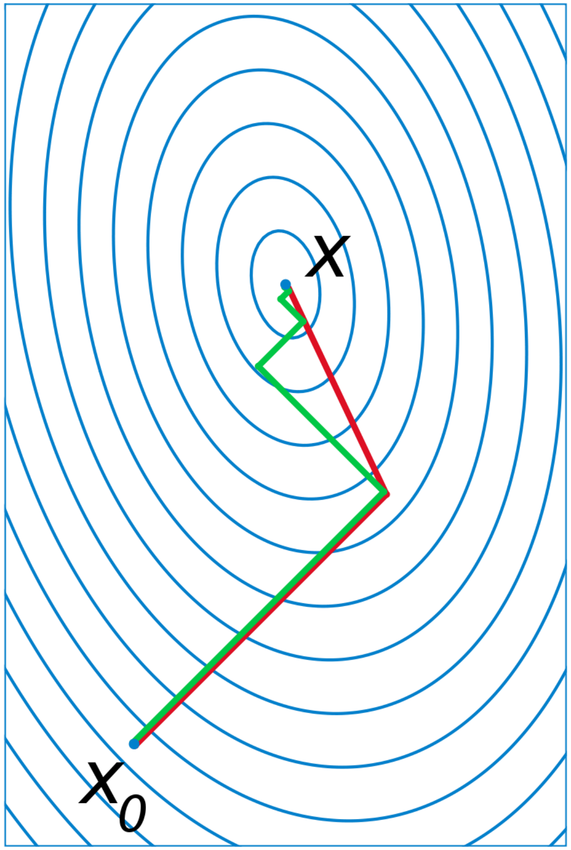

?
ANY QUESTIONS ?
IMDC

Conjugate gradient

$$\mathbf{A}\mathbf{x} = \mathbf{b}$$

$$f(\mathbf{x}) = \tfrac{1}{2}\mathbf{x}^\mathsf{T}\mathbf{A}\mathbf{x} - \mathbf{x}^\mathsf{T}\mathbf{b}, \qquad \mathbf{x} \in \mathbf{R}^n\,.$$

$$\nabla f(\mathbf{x}) = \mathbf{A}\mathbf{x} - \mathbf{b}\,.$$



LECTURE 3.1: TELEMAC problem solving (hands-on)

Alexander Breugem

Objective

- To learn to recognize the different kinds of problems
- To learns some basic techniques for solving them

- Please note:
  - Problem solving is an art
  - Goes better every time you get more experience

Overview

- Types of problems
  - Fortran
  - Cas file errors
  - Wrong meshes/cli files
  - Runtime errors
  - Instabilities/crashes
  - Unexpected results
- Techniques for diagnosing problems
  - Checking the mesh
  - Checking log files/output
  - Generate additional output
  - Change source code to get additional information

Fortran problems

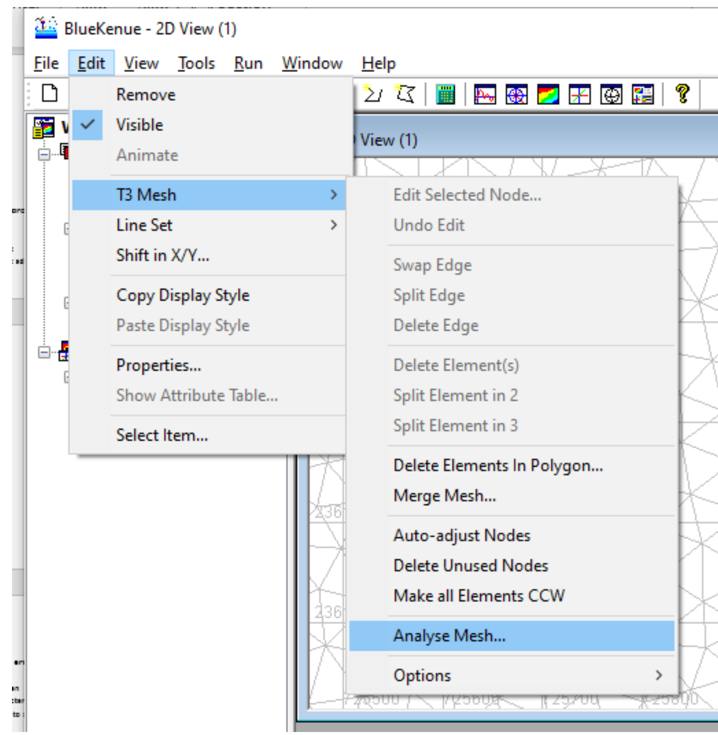
- Can happen when custom Fortran code is added to a test case

Cas file problems

- Wrong .cas files lead to an error
- Points of attention
  - // Only comment in between
  - Input longer than 72 characters
  - Forgotten ” (often difficult to spot)
  - Typos in keywords (use reference manual/.dico file)

Wrong mesh/cli files

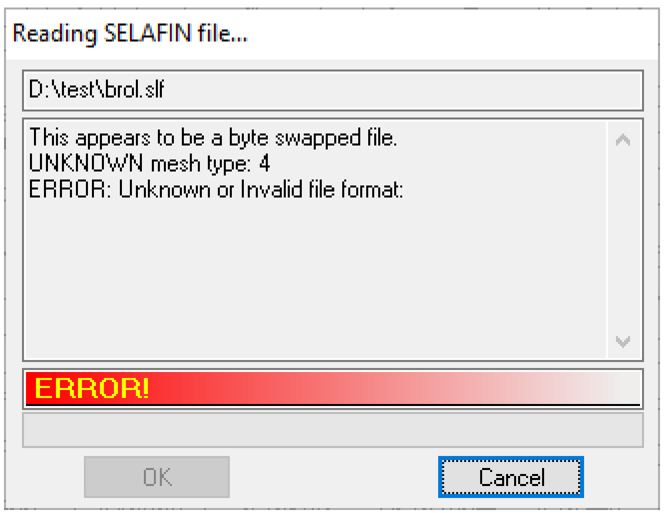
- Double triangle
- Double nodes
- Different number of boundary y points in .cli file as in .slf file
- Wrong values/wrong variable name
- Checks:
  - Reloading Selafin file in BlueKenue/making new Selafin object
  - Analyze mesh (in BlueKenue)
  - Make boundary condition object and view

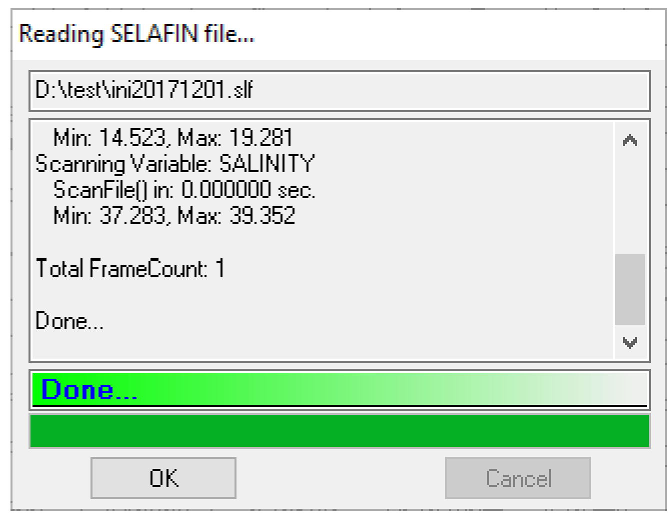


IMDC

Checking mesh files

- Loading in BlueKenue

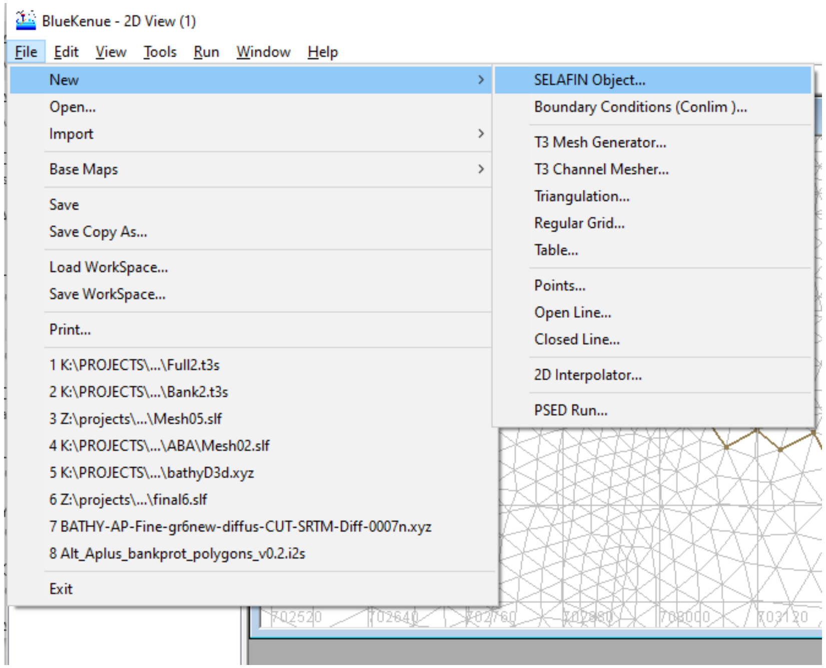




IMDC

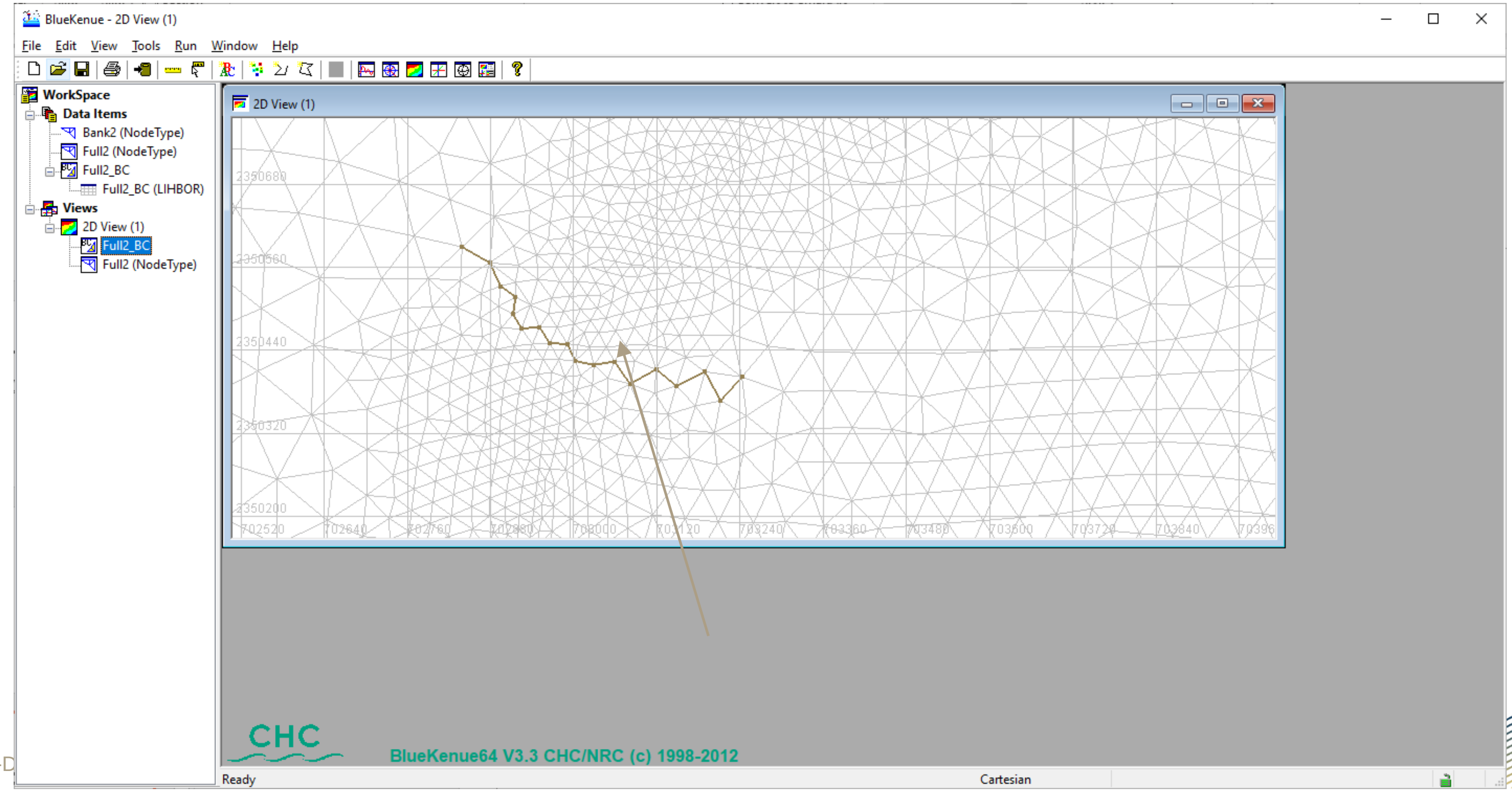
Wrong mesh cli files

- Rules to prevent problems
  - Always make new Selafin object when you change the mesh
  - Always make new cli file when you change the mesh



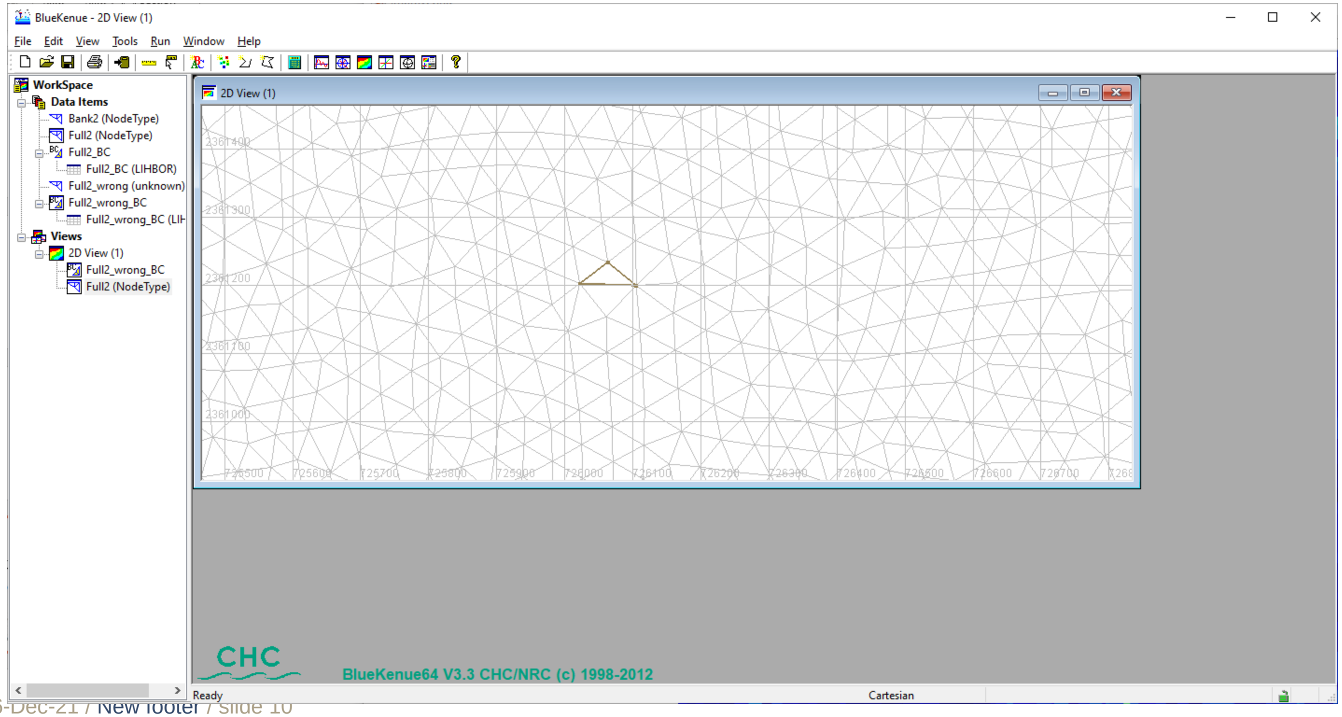
Wrong mesh: double points

- Check by making boundaries. You see unexpected boundaries.
- Can occur when merging meshes
- Solution: redo meshing/merging. Check for rounding errors in coordinates



Wrong mesh: double element

- Sometimes happens when using submeshes
- Solution:
  - Delete the element (T3Mesh toolbar)
  - Redo meshing (change outline not to include submesh)



Wrong mesh (double element); single processor

Anaconda Prompt

```
                     ************************************
                     *    END OF MEMORY ORGANIZATION:    *
                     ************************************

 K2=  2147483647  K1=          86
 ELEBD: ERROR AT POINT:          4
        THE BOUNDARY POINT:        86
        DOES NOT BELONG TO ELEMENT : 2147483647
        POSSIBLE REASONS:
        THE BOUNDARY CONDITION FILE IS NOT
        RELEVANT TO THE GEOMETRY FILE
        OR THE MESH HAS A WRONG TOPOLOGY

 PLANTE: PROGRAM STOPPED AFTER AN ERROR
 RETURNING EXIT CODE:             2

job aborted:
[ranks] message

[0] process exited without calling finalize

---- error analysis -----

[0] on IMDC-ABR-6
D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem04\t2d_canal.cas_2020-03-09-23h11min58s\out_telemac2d ended prematurely and may have
 crashed. exit code 1

---- error analysis -----
_____________
runcode::main:
:
   |runCode: Fail to run
   |mpiexec -wdir D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem04\t2d_canal.cas_2020-03-09-23h11min58s -n 1 D:\12182\01-training\
Training\02-selected\exercises\problemSolving\problem04\t2d_canal.cas_2020-03-09-23h11min58s\out_telemac2d
   |~~~~~~~~~~~~~~~~~~
   |STOP 1
   |~~~~~~~~~~~~~~~~~~

(base) D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem04>_
```

Type here to search ENG 23:12 09/03/2020

Wrong mesh: parallel

```
|            NUMBER OF POINTS:      319
|
|
|            FORMAT NOT INDICATED IN TITLE
|
|
|
| ONE-LEVEL MESH.
|
| NDP NODES PER ELEMENT:                     3
|
| ELEMENT TYPE :                            10
|
| NPOIN NUMBER OF MESH NODES:              319
|
| NELEM NUMBER OF MESH ELEMENTS:           552
|
|
| THE INPUT FILE ASSUMED TO BE 2D
|
| THERE ARE           1  TIME-DEPENDENT RECORDINGS
|
| K2=   807415856  K1=         86
|
```

Wrong mesh: wrong .cli file

- Cause: forgotten to update the .cli file
- Solution: remake .cli file
- Tip: save a .xyz file with location of the boundaries

Anaconda Prompt

```
DIMENSION 1 OF IKLE:          551
IELM0:            10
CORRXY (BIEF):NO MODIFICATION OF COORDINATES

MESH: MESH   ALLOCATED

                    *************************************
                    *    END OF MEMORY ORGANIZATION:    *
                    *************************************

POINT           80  IS ON A BOUNDARY
POINT           81  IS ON A BOUNDARY
BUT NOT IN THE LIST OF BOUNDARY POINTS
OR THE NUMBER OF LINES IN THE BOUNDARY
CONDITIONS FILE IS GREATER THAN:          81
NUMBER TAKEN IN THE GEOMETRY FILE

PLANTE: PROGRAM STOPPED AFTER AN ERROR
RETURNING EXIT CODE:            2

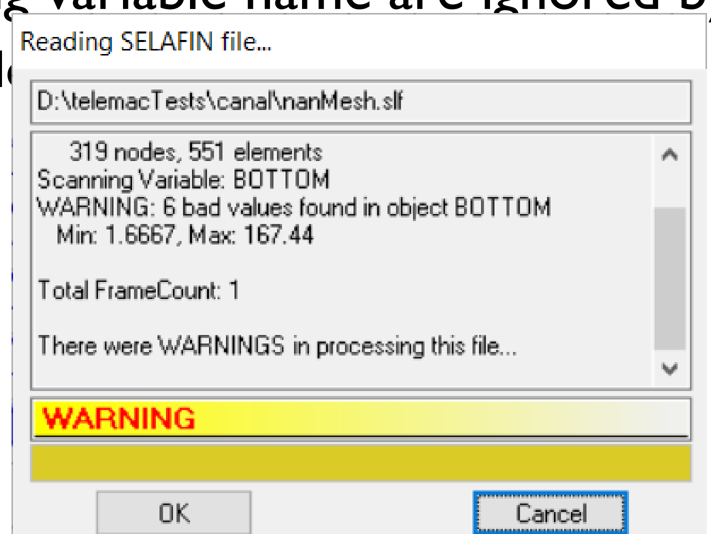
job aborted:
[ranks] message

[0] process exited without calling finalize
```


IMDC

Wrong values in the mesh

- Data in the mesh cannot have NaN values (e.g. division by zero)
- Solution: recompute variables
- Check for consist input
  - No negative water depths
  - Initial conditions and boundary conditions are compatible
  - Rigid bed is below bathymetry
- Variables with a wrong variable name are ignored by TELEMAC
  - Use suggested variabl



Runtime errors

- Error message generated by TELEMAC
- Typical problems
  - Incompatible settings in .CAS file
  - Erroneous input (e.g discharge om dry point)
  - Instabilities (extremely high velocities)

Example runtime error

Anaconda Prompt

```
 GRACJG (BIEF) :        1 ITERATIONS, ABSOLUTE PRECISION:   0.2744176E-04
--------------------------------------------------------------------------------
                       BALANCE OF WATER VOLUME
     VOLUME IN THE DOMAIN :    109140.5     M3
     FLUX BOUNDARY    1:    -0.000000     M3/S  ( >0 : ENTERING  <0 : EXITING )
     FLUX BOUNDARY    2:     600.0002     M3/S  ( >0 : ENTERING  <0 : EXITING )
     RELATIVE ERROR IN VOLUME AT T =        1800.     S :    0.1099422E-01
 T=   1802.0000000000000        OUT OF RANGE
 OF THE FILE OF LIQUID BOUNDARIES
 NUMBER OF LINES :            3
 SOME COMPILERS REQUIRE AN
 EMPTY LINE AT THE END OF THE FILE

 PLANTE: PROGRAM STOPPED AFTER AN ERROR
 RETURNING EXIT CODE:            2

job aborted:
[ranks] message

[0] process exited without calling finalize

---- error analysis -----

[0] on IMDC-ABR-6
D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem02\t2d_canal.cas_2020-03-09-22h55min05s\out_telemac2d ended prematurely and may have
 crashed. exit code 1

---- error analysis -----

_____________
runcode::main:
:
   |runCode: Fail to run
   |mpiexec -wdir D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem02\t2d_canal.cas_2020-03-09-22h55min05s -n 1 D:\12182\01-training\
Training\02-selected\exercises\problemSolving\problem02\t2d_canal.cas_2020-03-09-22h55min05s\out_telemac2d
   |~~~~~~~~~~~~~~~~~~
   |Note: The following floating-point exceptions are signalling: IEEE_DENORMAL
   |STOP 1
   |~~~~~~~~~~~~~~~~~~

(base) D:\12182\01-training\Training\02-selected\exercises\problemSolving\problem02>_
```

Unexpected results

- Check input (use the manual)
  - Names of variable in LIQUID BOUNDARY FILE
  - Boundary numbering
  - Names of variables in GEOMETRY FILE

Techniques for diagnosing/analyzing problems

Crashes/instabilities: inspecting the log files

- Need to be switch on log files
  - `telemac2d.py` **`-s`** `mycas.cas`
- There is one .log file per processor (in parallel)
  - myCas.cas_2020-02-26-11h05min19s.sortie
  - myCas.cas_2020-02-26-11h05min19s/PE00003-000001.LOG etc
- An error message has the text `PLANTE`
  - Look for the error (sometimes only on one processor)
  - See how to solve this (look up error text in source code)

IMDC

Crashes/instabilities: generating extra output

- Rerun model with following settings in the .cas file

```
GRAPHIC PRINTOUT PERIOD          : 1
LISTING PRINTOUT PERIOD          : 1
```

- Will generate large output files
- If necessary, merge output files (GRETEL)

```
telemac 2d.py --merge -w myWorkDir
```

- Inspect the file to see where the crash/problem occurs
- Solve the problem

IMDC

Crashes/instabilities: using Fortran to detect problems

- Last resort if everything else fails
- Rerun with in the .cas file

```
DEBUGGER : 1
```

- Add guilty fortran routine to .cas file

```
FORTRAN FILE : wrongFile.f
```

- Write extra output to the .log files\\

```
WRITE (LU,*) 'WRONG VARIABLE',WRONG_VAR
```


IMDC

Crashes/instabilities: typical remedies/issues

- Decrease time step
- Change numerical parameters
  - Advection scheme
  - Solver (use GMRES)
  - Free surface gradient compatibility (decrease)
- Inspect mesh.
  - Bad elements
  - Strong gradients in bathymetry (especially near drying flooding)
  - Make sure bathymetry is deep at inflow
- Inspect other input
  - Water level initial condition and boundary condition the same?
  - Rigid bed below bottom?

LECTURE 2.4: TELEMAC problem solving

Alexander Breugem

IMDC

Objective

- To change the footer : go to view, slide master, click in the lower left corner of the slide

IMDC

Note

- Problem solving is an art
- Only comes with experience

Overview

- Types of problems
  - Fortran
  - Cas file errors
  - Wrong meshes/cli files
  - Runtime errors
  - Instabilities/crashes
  - Unexpected results
- Techniques for diagnosing problems
  - Checking the mesh
  - Checking log files/output
  - Generate additional output
  - Change source code to get additional information

Fortran problems

- Happens whenm

Cas file problems

- Wrong .cas files lead to an error
- Points of attention
  - // Only comment in between
  - Input longer than 72 characters
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  - Typos in keywords

IMDC

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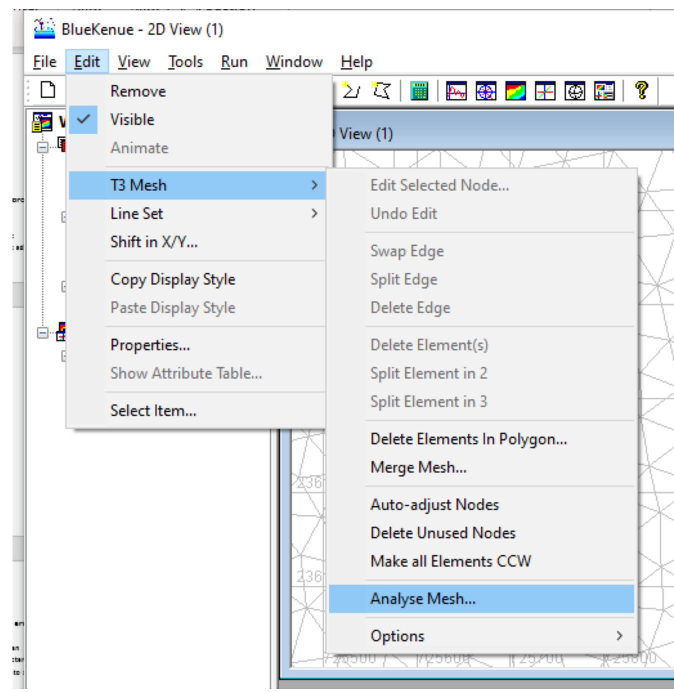
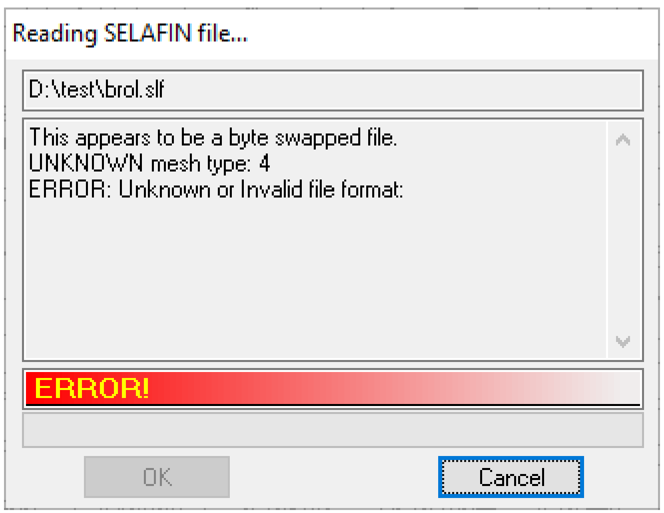
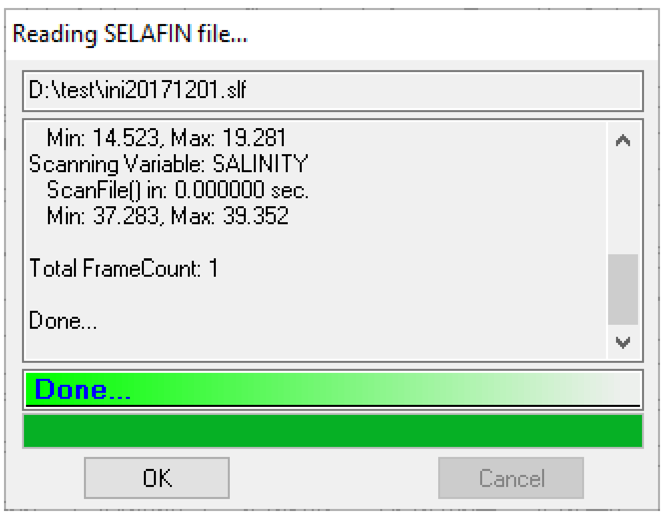


Checking mesh files

- Loading in BlueKenue

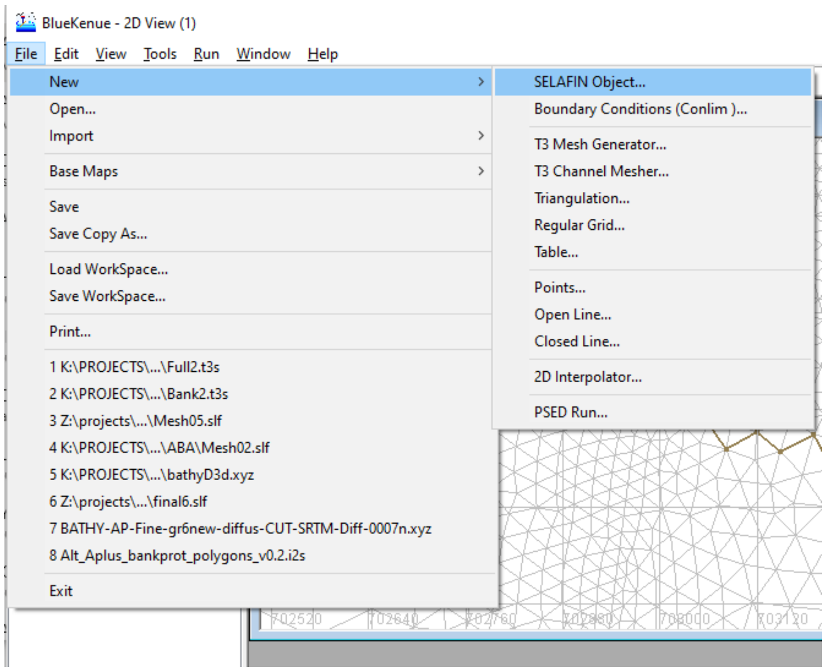




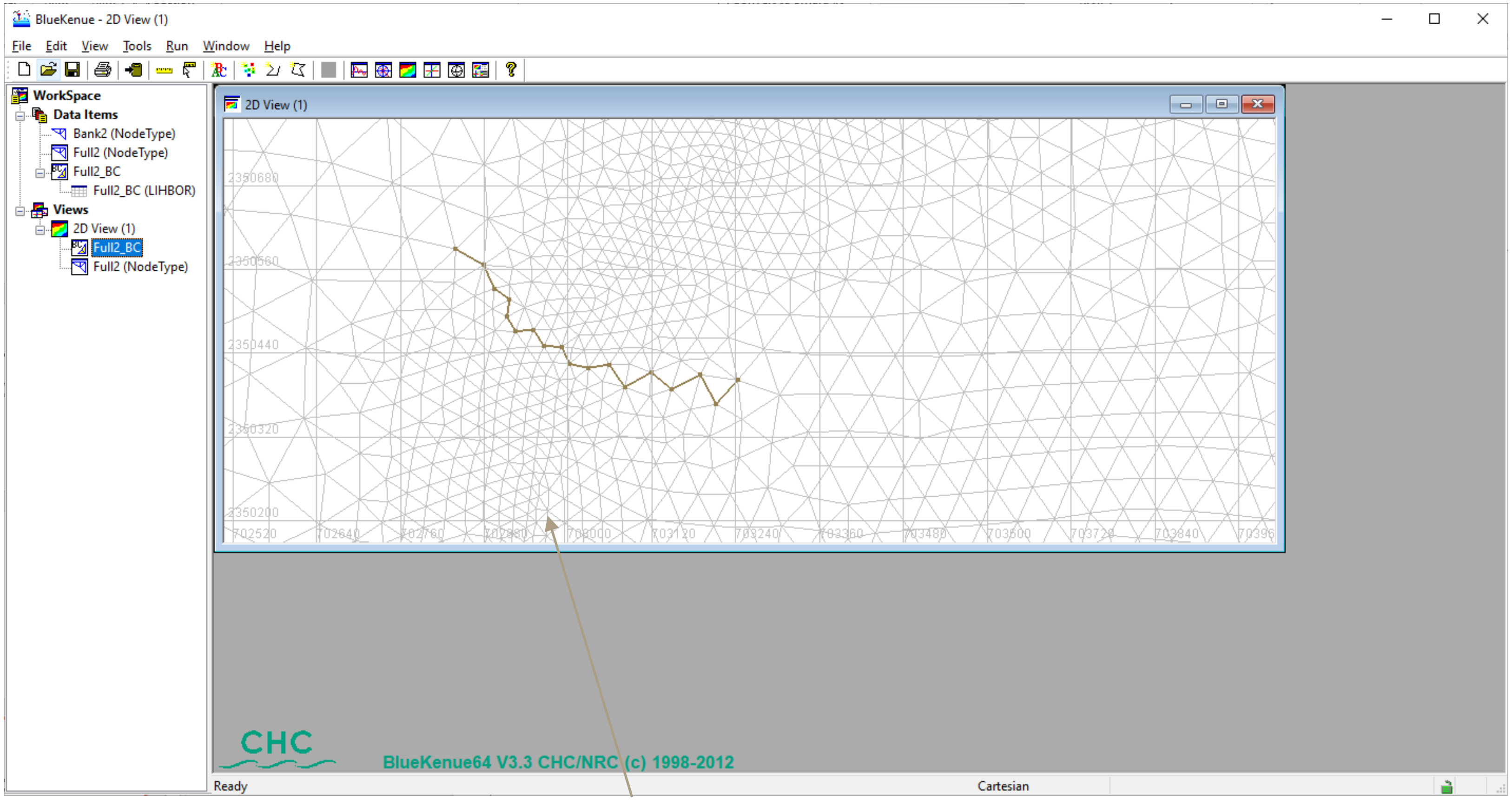
IMDC

Wrong mesh cli files

- Rules to prevent problems
  - Always make new Selafin object when you change the mesh
  - Always make new cli file when you change the mesh

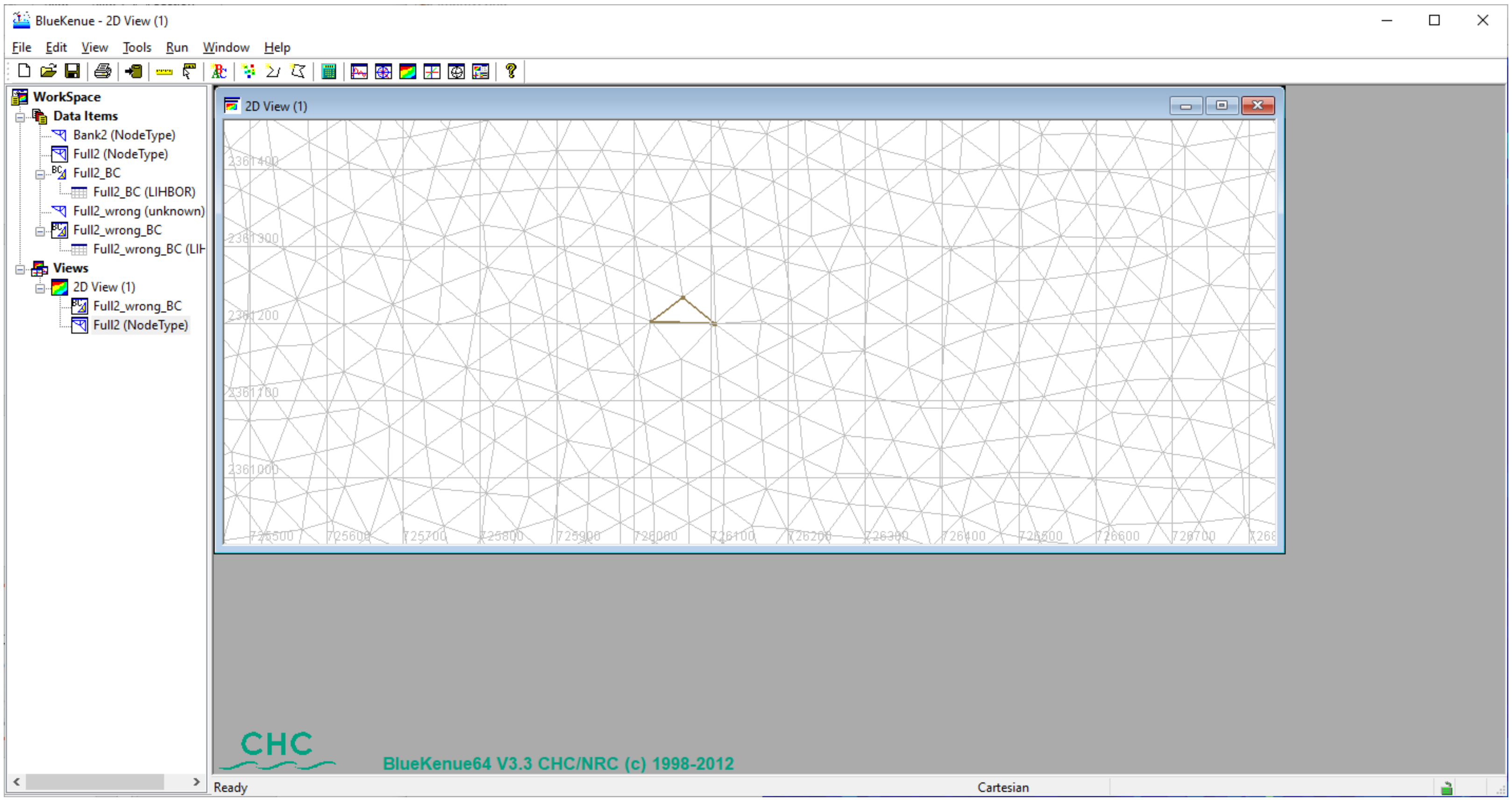


Wrong mesh: double points



IMDC

Wrong mesh: double element



IMDC

Wrong mesh: wrong .cli file

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- Check for consist input
  - No negative water depths
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- Variables with a wrong variable name are ignored by TELEMAC
  - Use suggested variable names by BlueKenue.

IMDC

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- Typical problems
  - Incompatible settings in .CAS file
  - Erroneous input (e.g discharge om dry point)
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IMDC

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IMDC

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IMDC

Crashes/instabilities: generating extra output

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GRAPHIC PRINTOUT PERIOD        : 1
LISTING PRINTOUT PERIOD        : 1
```

- Will generate large output files
- If necessary, merge output files (GRETEL)

```
telemac 2d.py --merge -w myWorkDir
```

- Inspect the file to see where the crash/problem occurs
- Solve the problem

IMDC

Crashes/instabilities: using Fortran to detect problems

- Last resort if everything else fails
- Rerun with in the .cas file

```
DEBUGGER : 1
```

- Add guilty fortran routine to .cas file

```
FORTRAN FILE : wrongFile.f
```

- Write extra output to the .log files\\

```
WRITE (LU,*) ‘WRONG VARIABLE’,WRONG_VAR
```

Crashes/instabilities: typical remedies/issues

- Change time step
- Change numerical parameters
  - Advection scheme
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  - Free surface gradient compatibility (decrease)
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  - Strong gradients in bathymetry (especially near drying flooding)
  - Make sure bathymetry is deep at inflow
- Inspect other input
  - Water level initial condition and boundary condition the same?
  - Rigid bed below bottom?

LECTURE 3.3/3.4: Adriatic and Istria Model

Alexander Breugem

IMDC

Objective

- To learn about the model of the Adriatic Sea
- To learns about the Istria Water Quality model

IMDC

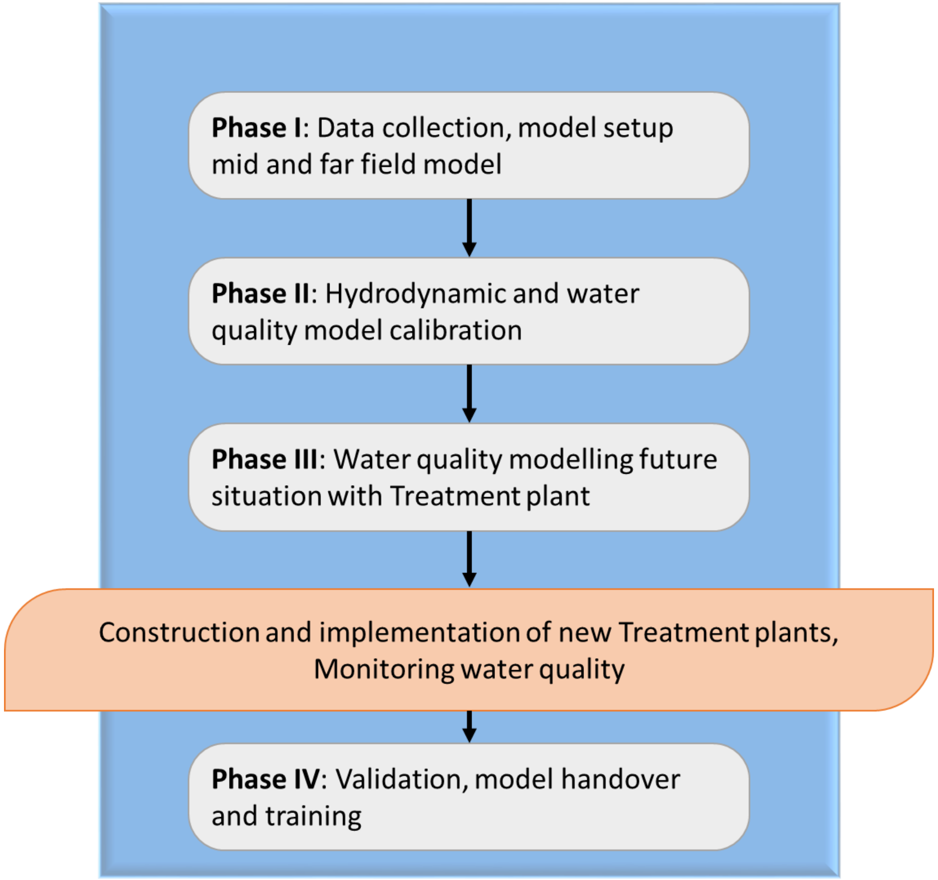
Overview

- Discuss the Adriatic and Istria Model
  - Objective
  - Used model data/system analysis
  - Model setup
    - Mesh
    - Boundary conditions
    - Initial conditions
    - Forcing
    - Settings (.cas file)

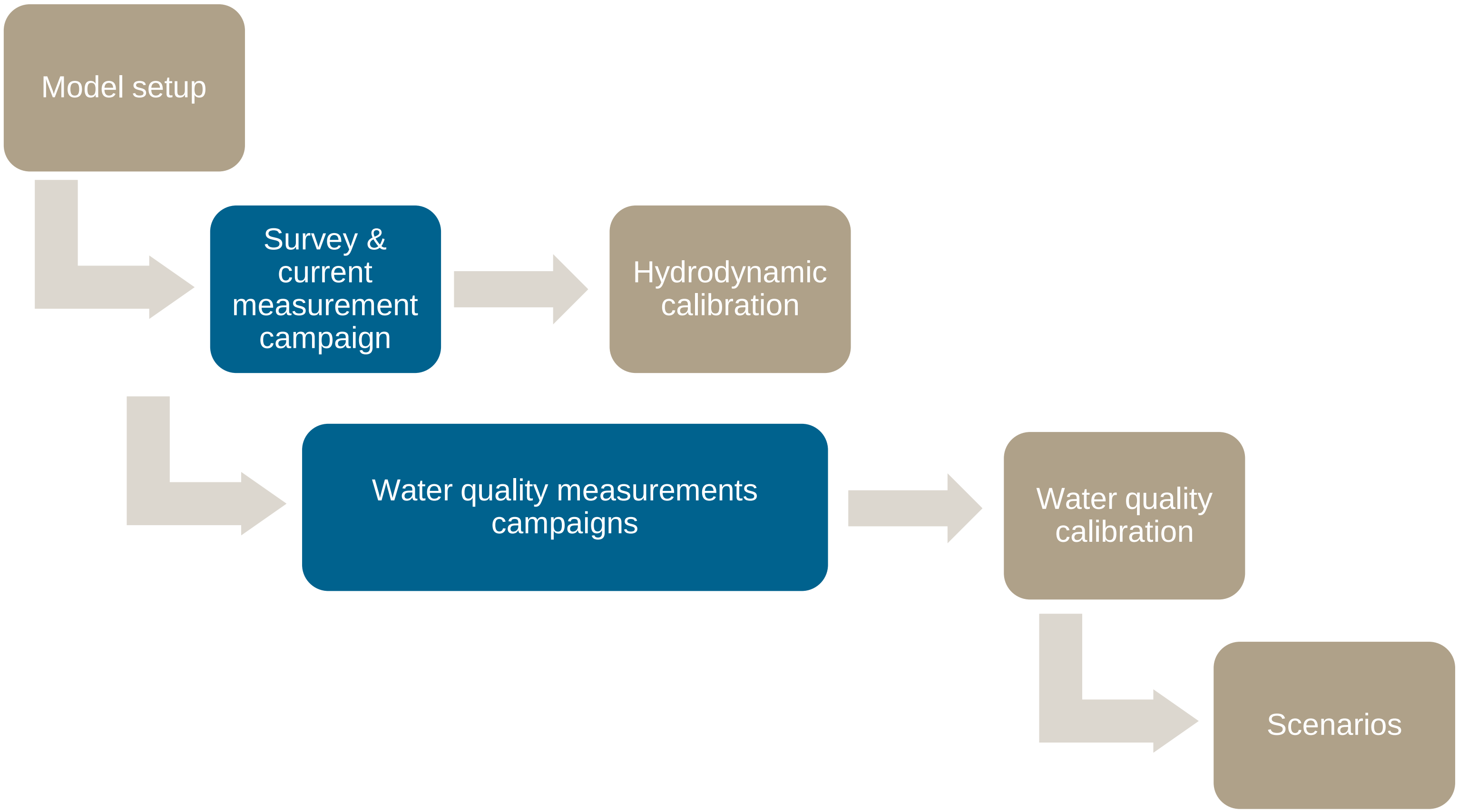
  - Calibration/validation
    - Hydrodynamics
    - Water quality

IMDC

Introduction



Modelling works



IMDC

Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

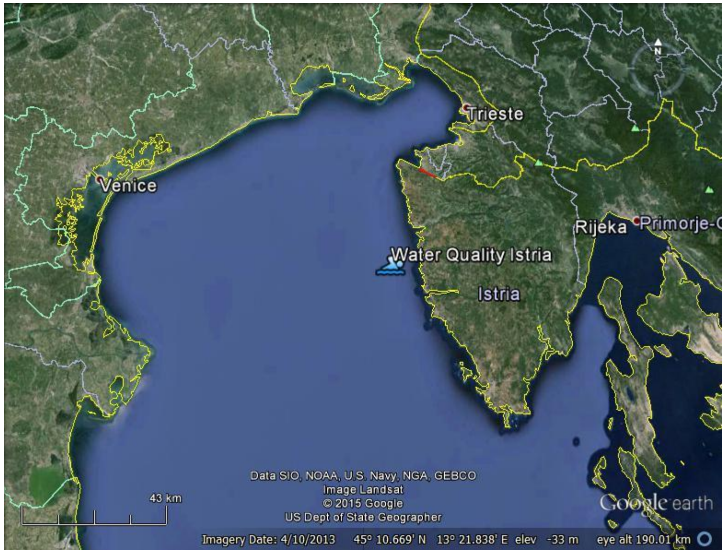
1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions
5. Simulation organisation
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

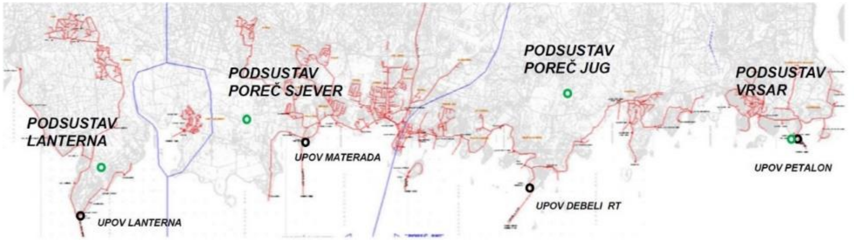
IMDC

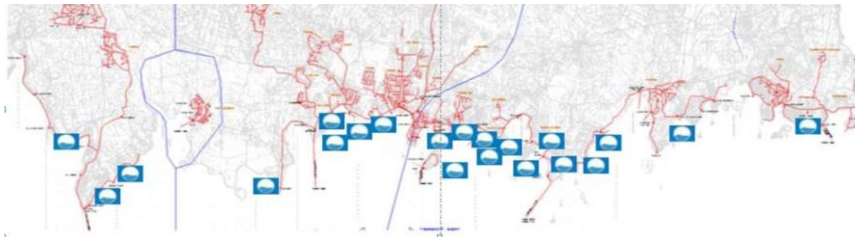
Introduction

Objective:

- sea water quality modelling of the dispersion of sewage effluent (fecal bacteria) along the Istrian coast, Croatia
- asses the risk of E-Coli (EC) and Intestinal Enterococci (IE) pollution at the beaches and the added value of treatment plants to reduce this risk







Hydrodynamic Flow modelling

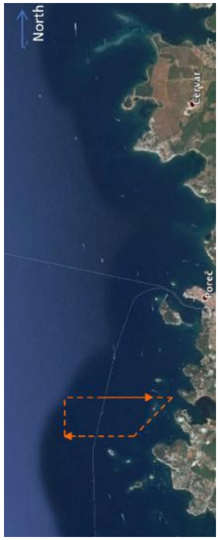
Steps in the setup of a hydrodynamic model

1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions
5. Simulation organisation
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

IMDC

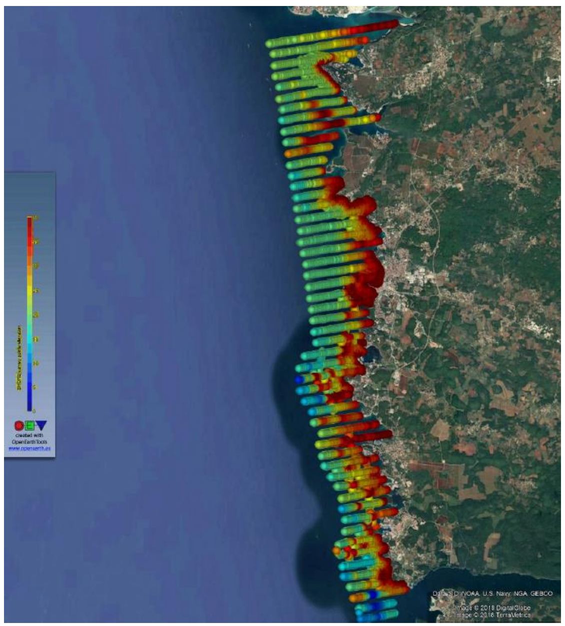
Survey campaign

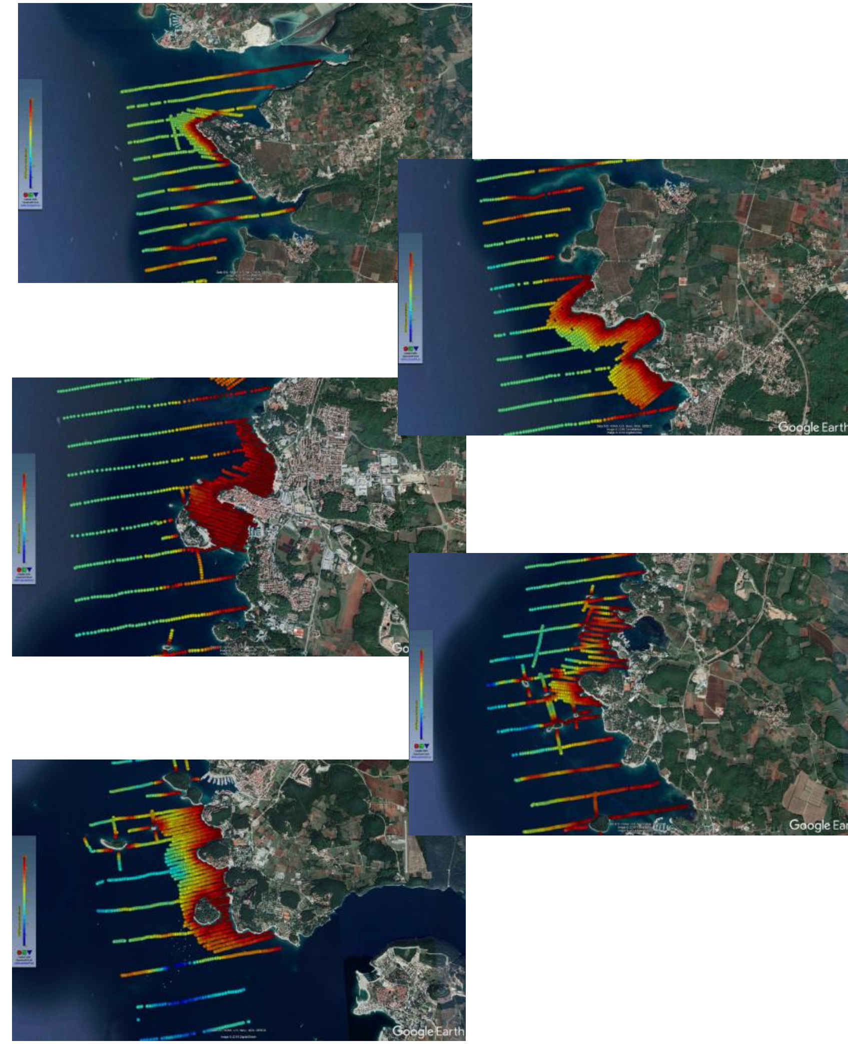
- Measurement of bathymetry and currents by SHORE
- Goals:
  - Support model setup
  - Calibration hydrodynam model
- Status: finished



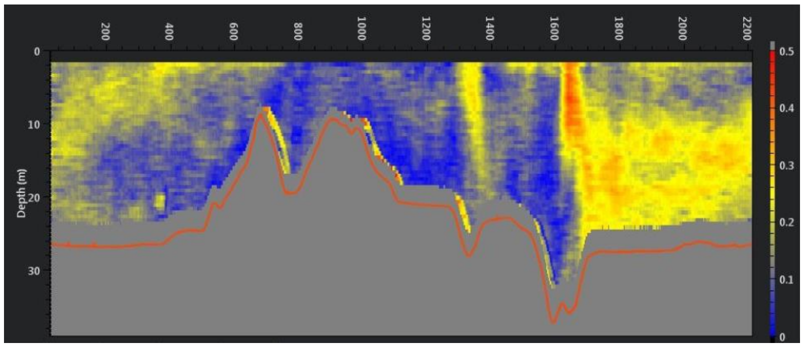
Survey campaign – bathymetric results

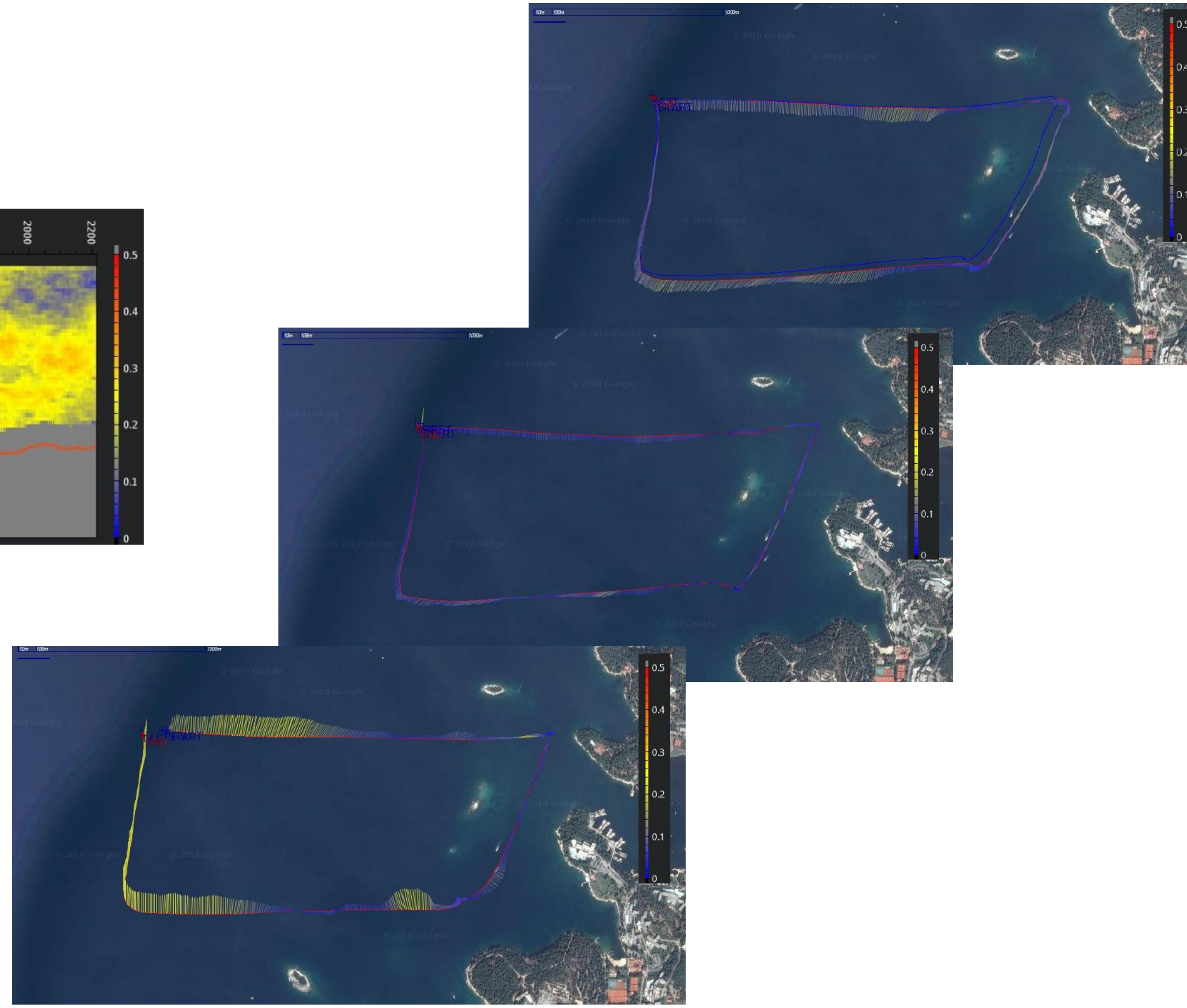
Range: -40 to -1 mMSL



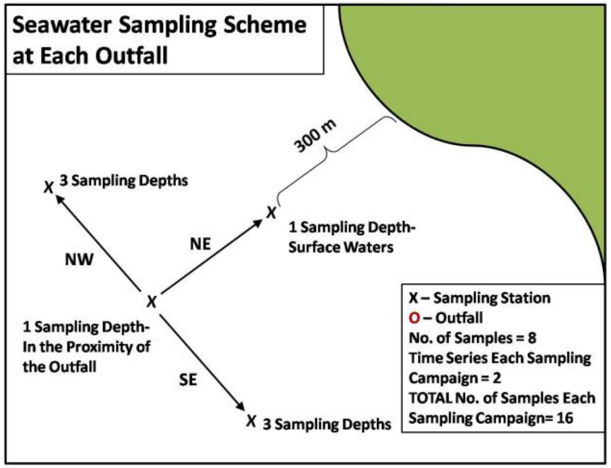


Survey campaign – ADCP data





Water quality measurement campaigns



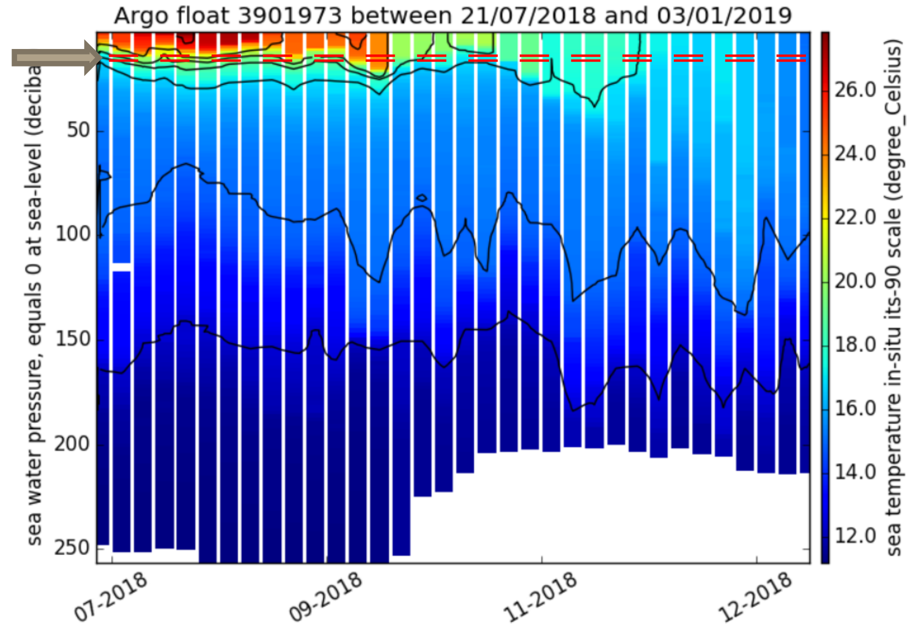
- Measurements of concentrations of EC in winter and summer and decay rate experiment in summer by IRB
- Goals:
  - Support model setup
  - Calibration water quality model
- Status:
  - Finished

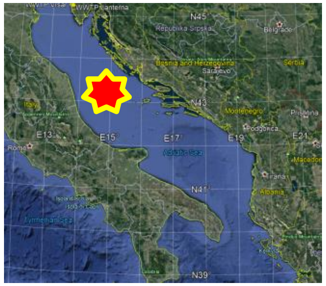
Outfall	Collection Tank Range EC (cfu/100ml)	Sea Range EC (cfu/100ml)
Lanterna	4 – 14 e+6	3 – 64
Porec North	4 – 21 e+6	1 – 9400
Porec South	8 – 13 e+6	7 – 60
Vrsar	11 – 61 e+6	13 – 62

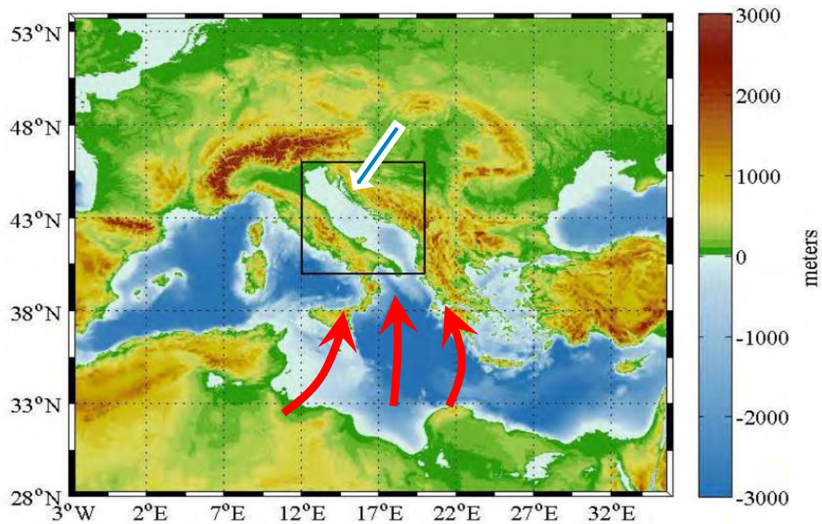
IMDC

Data analysis - general information

- Small tidal variations
- Small currents
- Importance of wind events
- Occurrence of stratification (winter/summer)





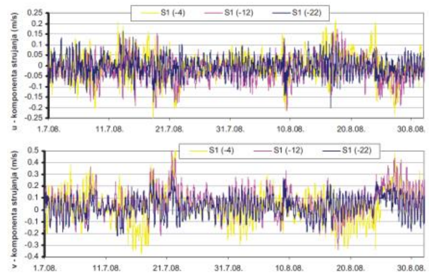


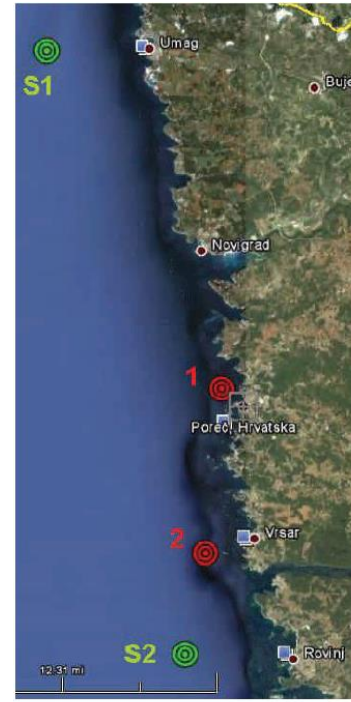
Bora wind (winter)
Sirocco/Jugo wind (rest of the year)

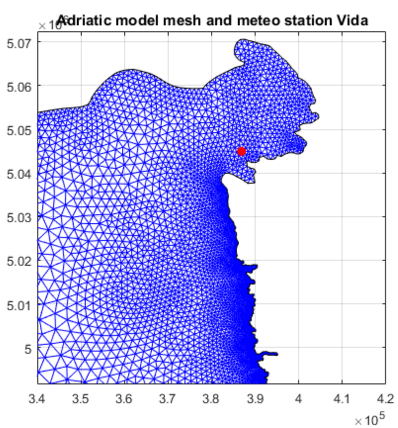
IMDC

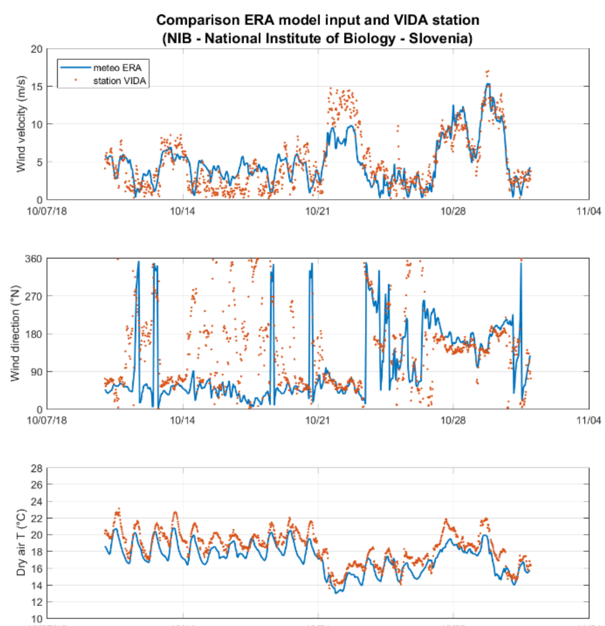
Data collection for hydrodynamic calibration

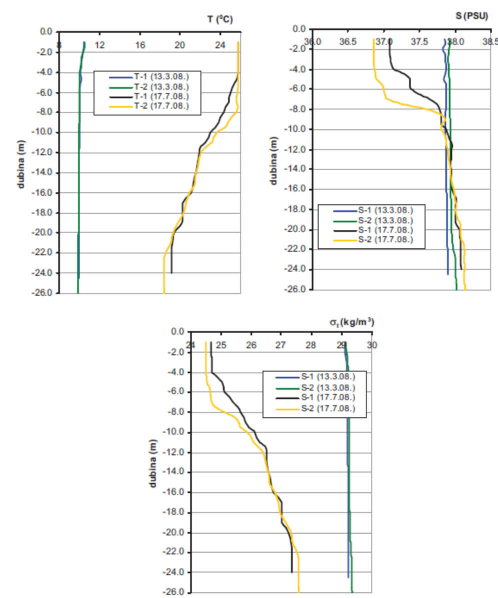
- Water level data
- Wind measurements (VIDA)
- Currents: ADCP data (winter)
- CTD data
  (survey – winter)
  (literature – summer)







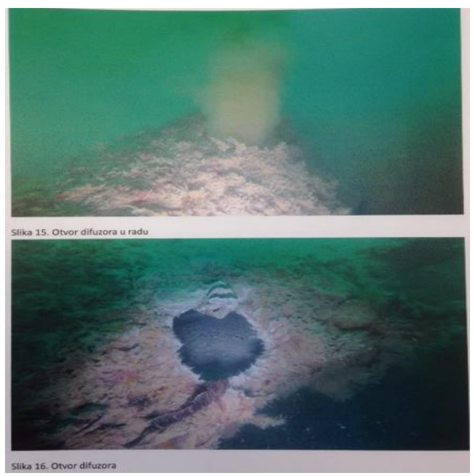


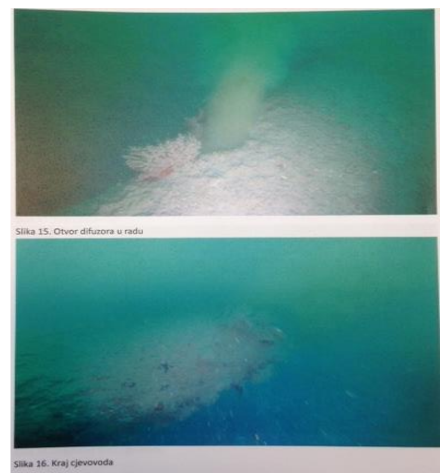


IMDC

Outfall data

Outfall	V_{basin} (m^3)	Q_{max} (m^3)	T_{flush} (s)	Piping					Diffusor			
				Dpipe (m)	Lpipe,land (m)	Vpipe,land (m^3)	Lpipe,sea (m)	Vpipe,sea (m^3)	Ldiff (m)	# openings	D opening	Depth
Porec Sjever	30-50	0.15	200-330 s	0.5	110	22	900	177	100	20	0.1	25
Porec Jug	30-50	0.2	150-250 s	0.5	200	39	800	157	90	20	0.1	24
Lanterna	10	0.15	67 s	0.5	120	24	500	98	86	13	0.1	25
Vrsar	15-25	0.075	200-330 s	0.5	70	14	418	82	-	1	0.5	30



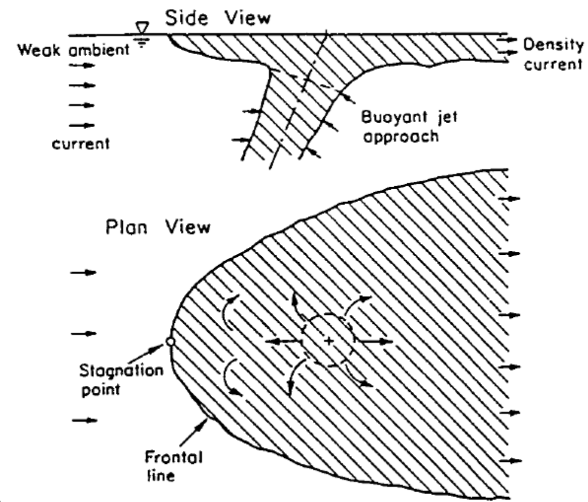


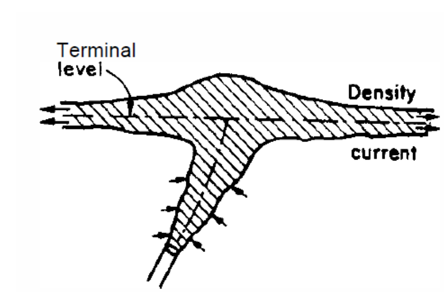
IHE UNESCO reports

Model setup

Relevant features to be captured:

- Initial mixing
- 3D processes (stratification in Summer)
- Tide and wind effects in currents
- Transport processes of bacteries due to tides a
- Decay rate of bacteria
- Seasonal variations
  - **Model for summer**
  - **Model for winter**



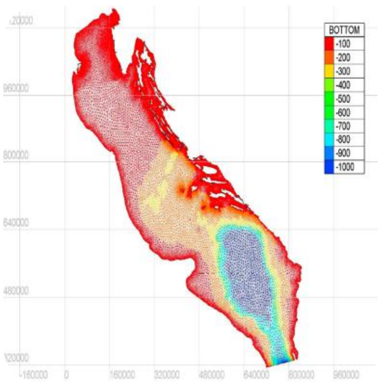


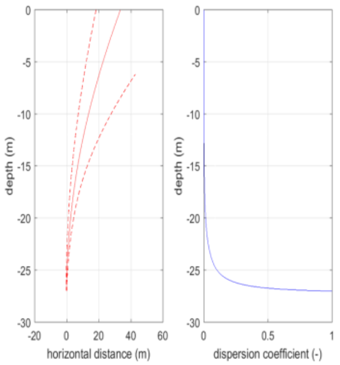
Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions
5. Simulation organisation
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

Model setup – model train





Far field

- Adriatic model
- Generates hydrodynamic boundary conditions

Mid field

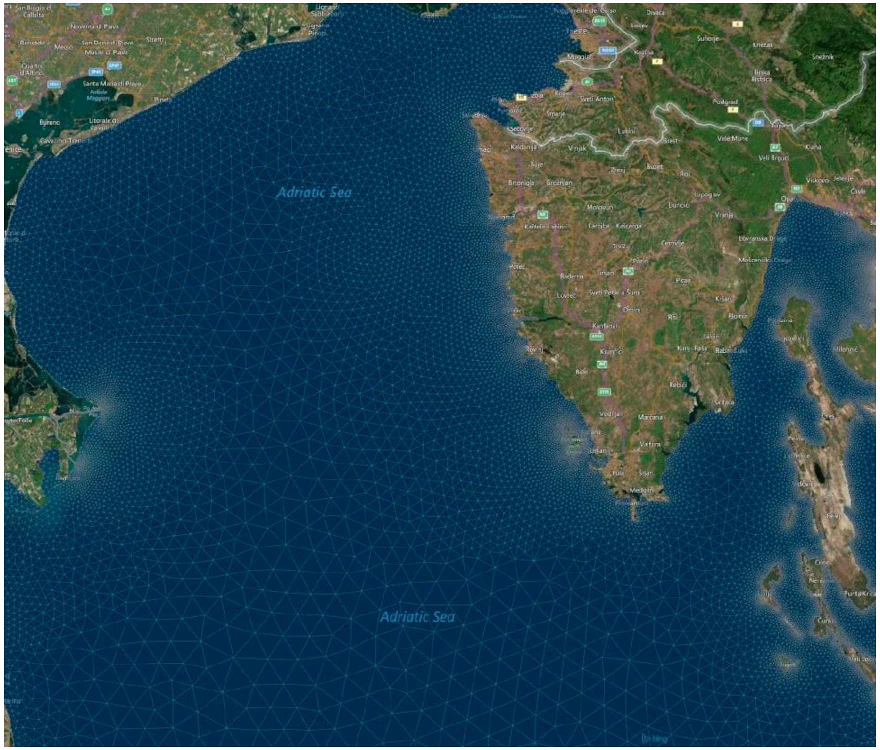
- Local coastal model
- **Study dispersion and fate EC bacteries**

Near field

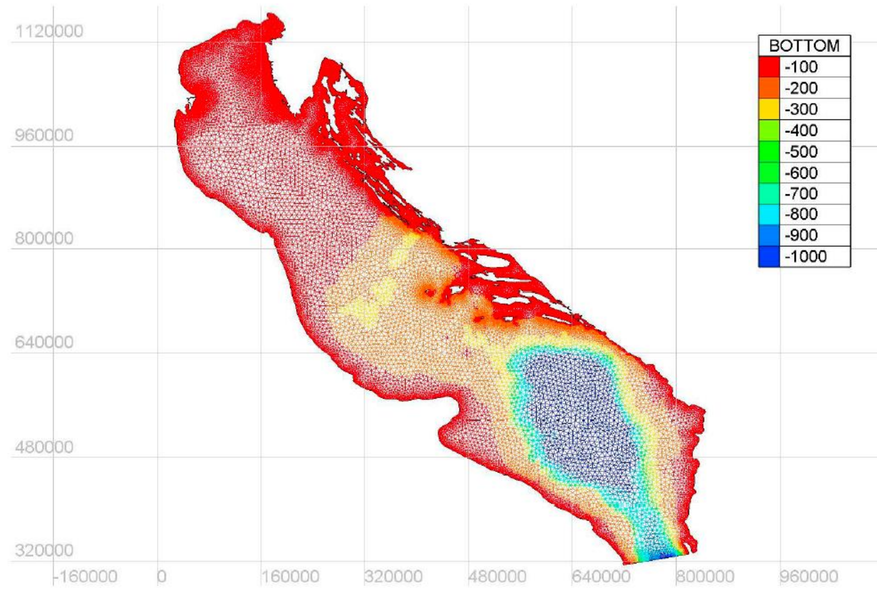
- Schematize initial mixing
- Generates boundary conditions EC bacteries

IMDC

Model setup – Far field model



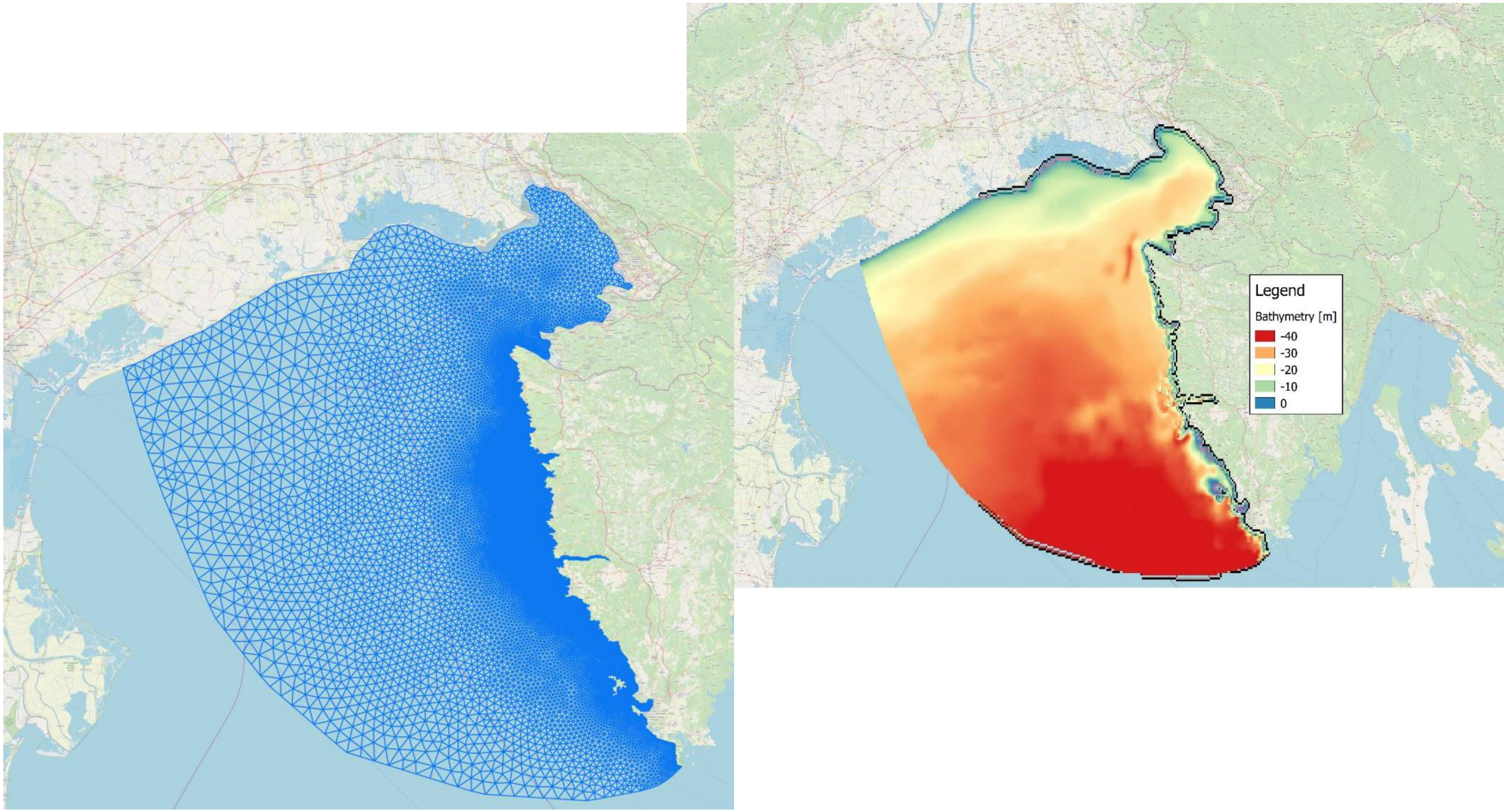
Model setup – Far field model



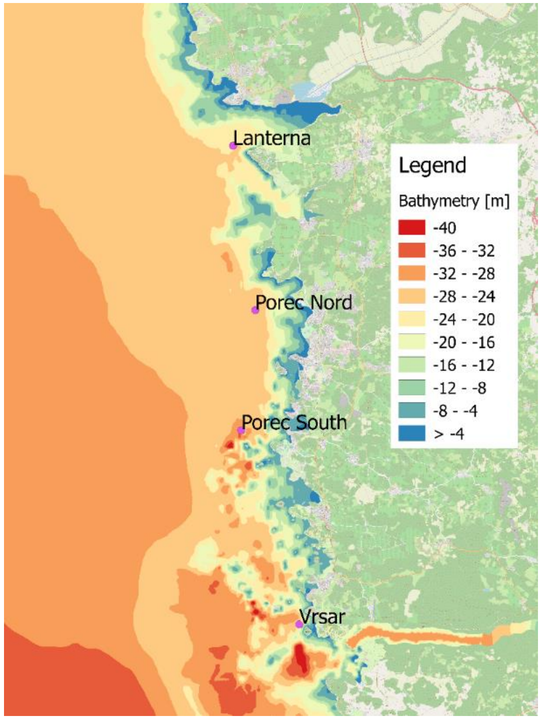
- Settings:
  - 20 vertical nodes (double sigma)
  - Boundary at Strait of Otranto
    - H, V, T, S
    - Data from TPXO and NEMO
  - Meteorological forcing (wind and pressure)
  - Turbulence model
    - Horizontal: Smagorinsky
    - Vertical: GOTM (k-epsilon)
  - Atmospheric exchange (air temperature)
  - Variation of density due to T and S

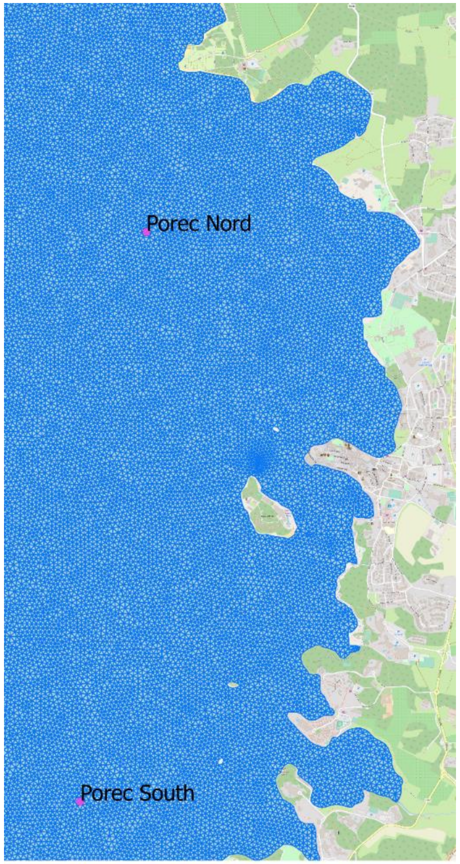
IMDC

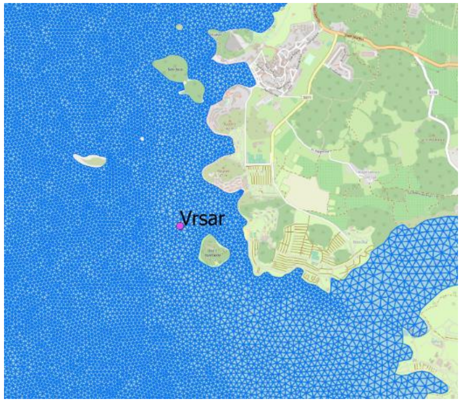
Model setup – Mid field model



Model setup – Mid field model







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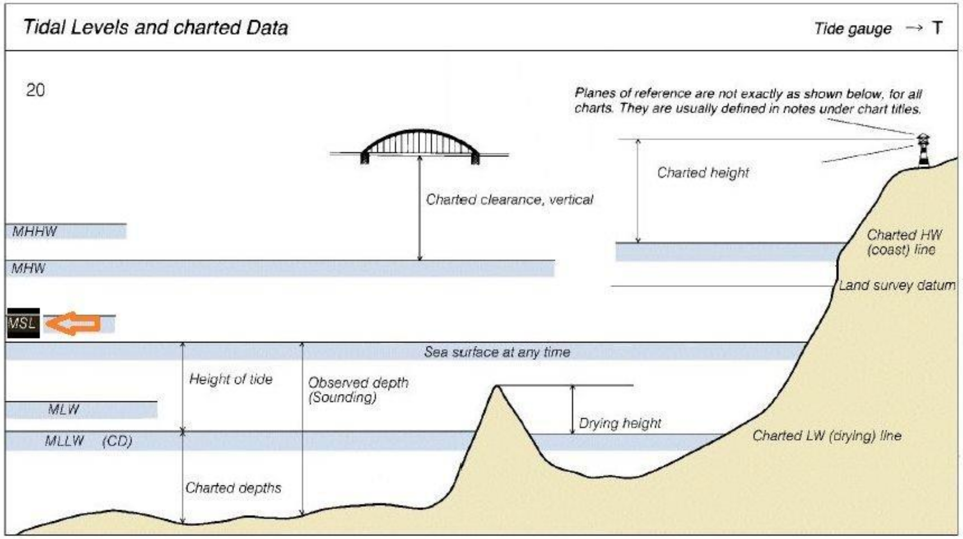
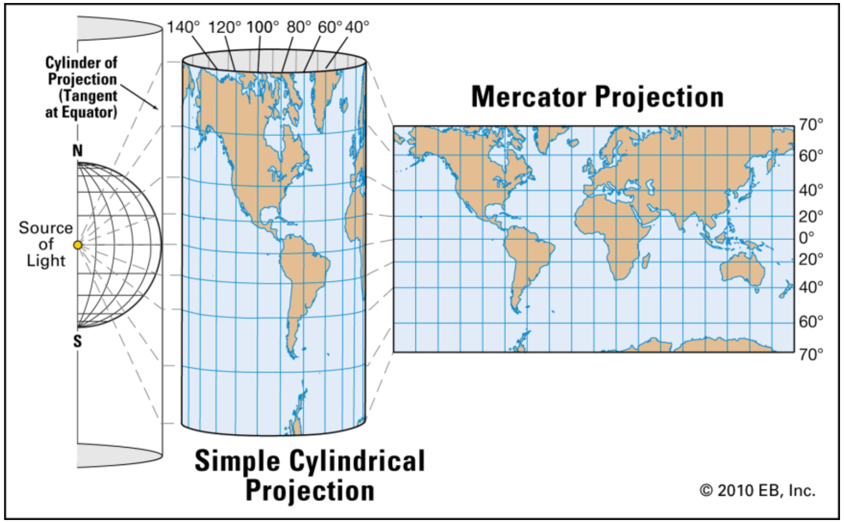
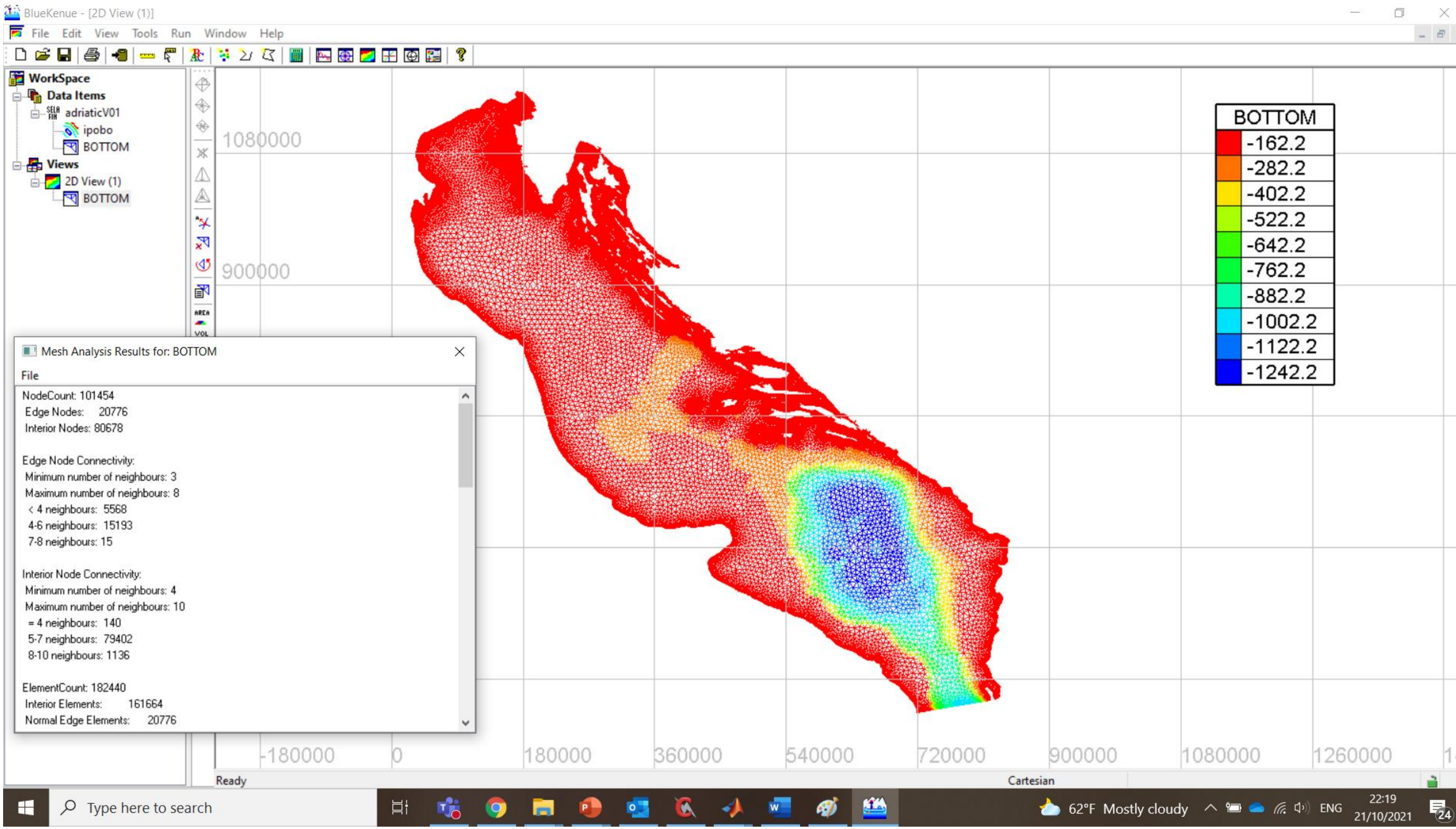
Coordinate systems

- Horizontal: Mercator for TELEMAC
- Vertical: Mean Sea Level
- Time: UTC



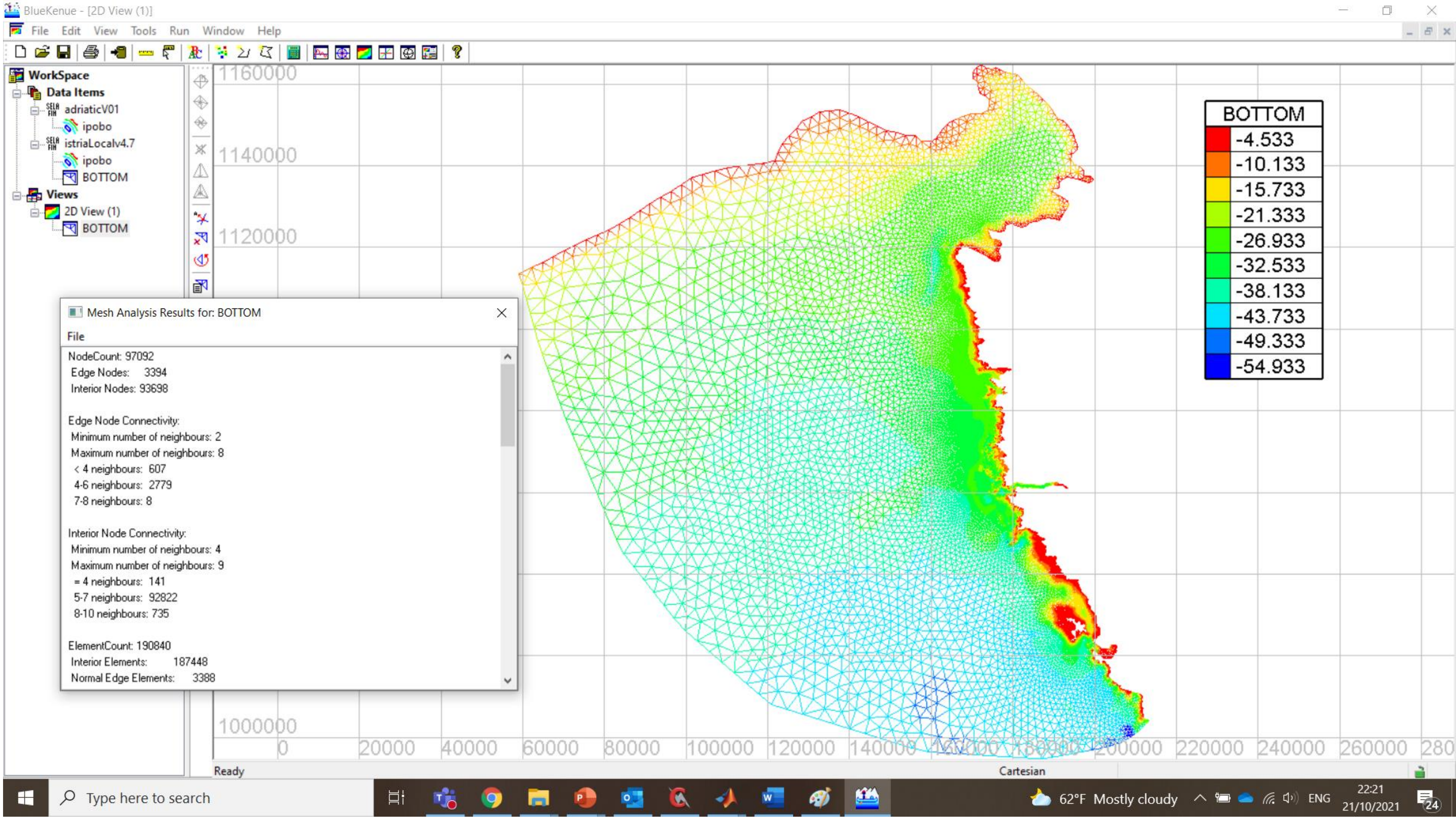


Mesh and bathymetry (Adriatic model)



IMDC

Mesh and bathymetry (Istria Model)



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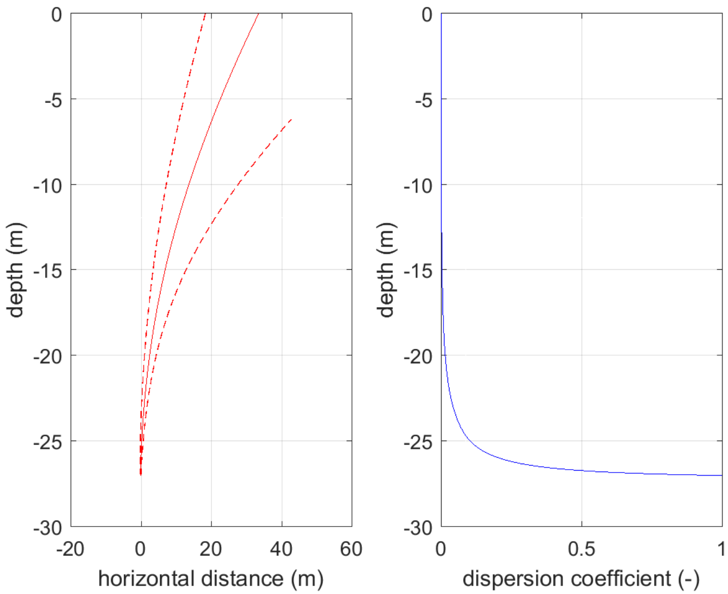
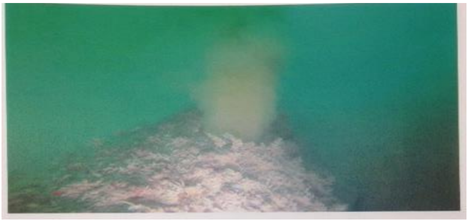
Mesh (overview)

- Open the Mesh in BlueKenue (*.slf file)
- Select correct colour scale
  - Right mouse -> Properties ->Colour Scale
- View resolution:
  - Tools -> T3DMesh -> Extract EdgeLengths
- Mesh properties
  - Edit -> T3D Mesh -> Analyse mesh
- 3D visualization
  - Make polylines
  - Tools -> T3D Mesh -> Extract Subset
  - New 3D view
  - Drag subset to new 3D view

Model setup – Near field

- Preliminary results
- Initial mixing depends on
  - Temperature and salinity effluent
  - Temperature and salinity sea water
  - Effluent velocity
  - Ambient velocity
- Good time series of discharges from basin required to generate input for the mid field model
  - Hydraulic calculation of discharges
    (pump time series, design collection tanks and siphons)





IMDC

Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions/initial conditions/forcing
5. Simulation organisation
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

Initial conditions

- Binary file (3D selafin file)
- Can be read in BlueKenue
- Data
  - Layer distribution
  - Velocity
  - Bathymetry
  - Salinity Temperature
- Needs to be updated when:
  - The mesh changes
  - The bathymetry changes (**taken from this file!**)

Forcing (meteo)

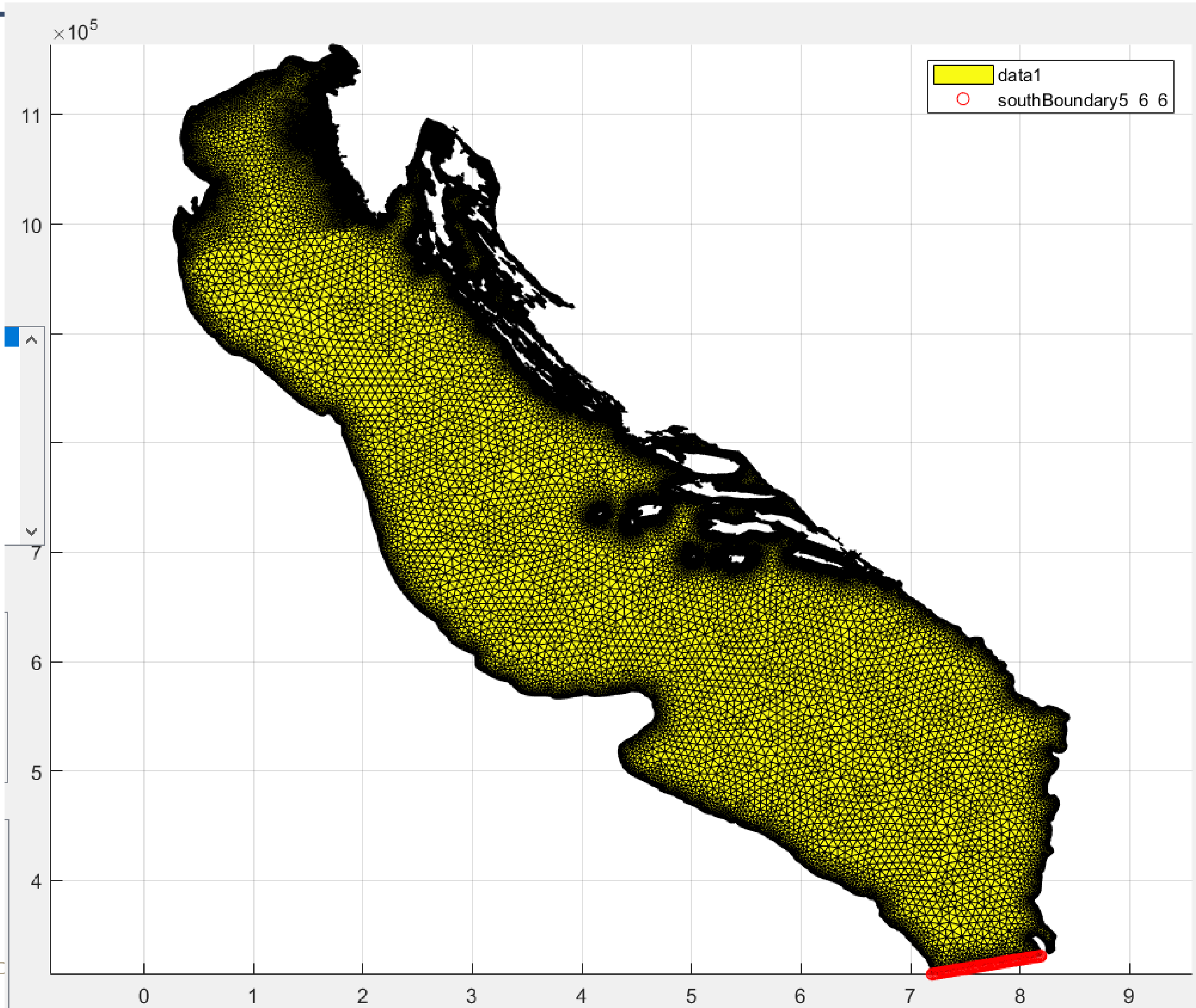
- Selafin file (binary file ; can be read by BlueKenue)
  - wind (at 10 m elevation)
  - atmospheric pressure
  - air temperature (at 2 m elevation)

IMDC

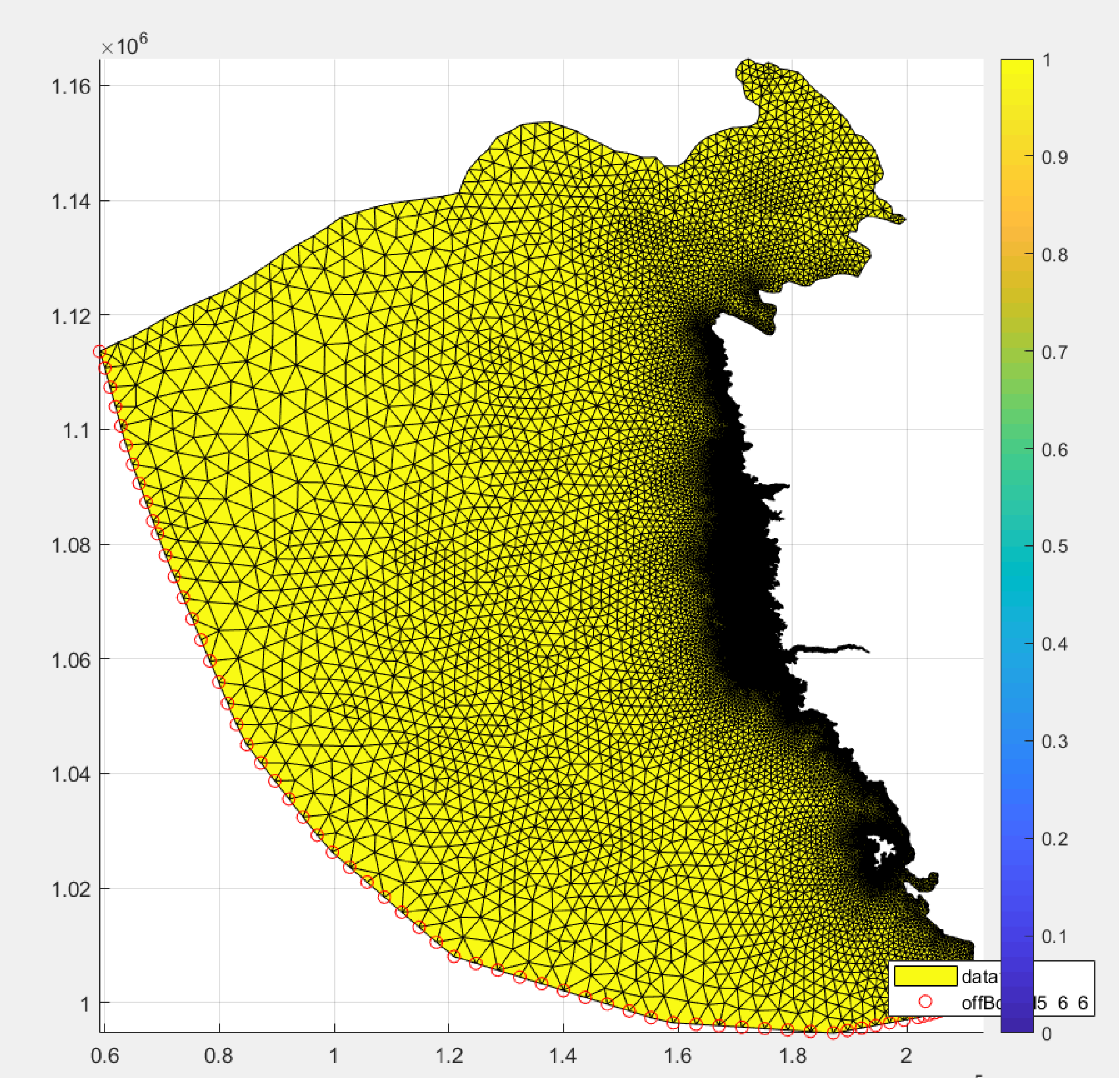
Boundary conditions

- Use .slf file (binary boundary condition)
  - Weird selafin format; **cannot be read by BlueKenue**
  - Contains vertical variation over the boundary (salinity, temperature)
  - For Adriatic model, Tide is added to data in the boundary condition file

Boundary conditions (Adriatic model)



Boundary condition (Istria model)



Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions/initial conditions/forcing
5. Simulation organization: model settings
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

IMDC

Settings (Adriatic model)

- TELEMAC-3D: adriatic.cas
  - vertical layers in condim.f
- WAQTEL: waqsteering.cas
- GOTM: gotm-input.nml

Settings (Istria model)

- TELEMAC-3D: istria.cas
  - vertical layers in condim.f
  - decay rate: DC.txt (IMDC extension)
  - fecal bacteria: srce01.txt to srce04.txt
- WAQTEL: waqsteering.cas
- GOTM: gotm-input.nml

IMDC

Hydrodynamic Flow modelling

Steps in the setup of a hydrodynamic model

1. Determine model objective
2. Data basis & system knowledge
3. Meshing
4. Boundary conditions
5. Simulation organisation
6. Sensitivity analysis
7. Calibration (strategy)
8. Validation

IMDC

Boundary conditions/initial conditions (far field model)

- Tide (water levels and velocities):
  - OSU-TPXO (Satelite data)
- Salinity/Temperature/Long term water level variations
  - NEMO-model (marine Copernicus)
- Meteo (wind, air temperature, atmospheric pressure)
  - ERA-5 model
- PO River (fresh water discharge; source term)
  - Typical value for the considered month

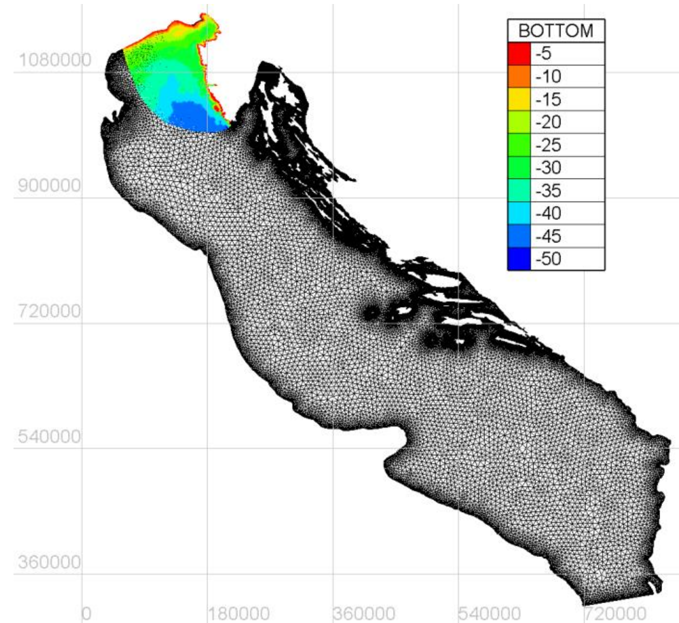
Boundary conditions/initial conditions (far field model)

- Water levels/velocities/temperature/salinity
  - From far field model
- Meteo (wind, air temperature, atmospheric pressure)
  - ERA-5 model

IMDC

Hydrodynamic calibration

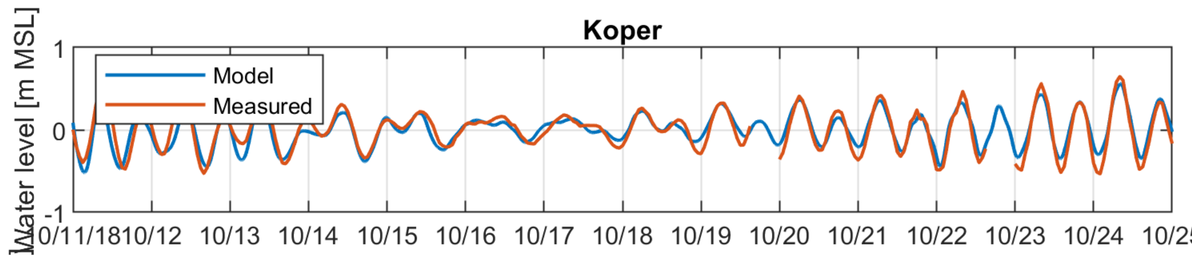
Focus on far field Adriatic model and mid-field model

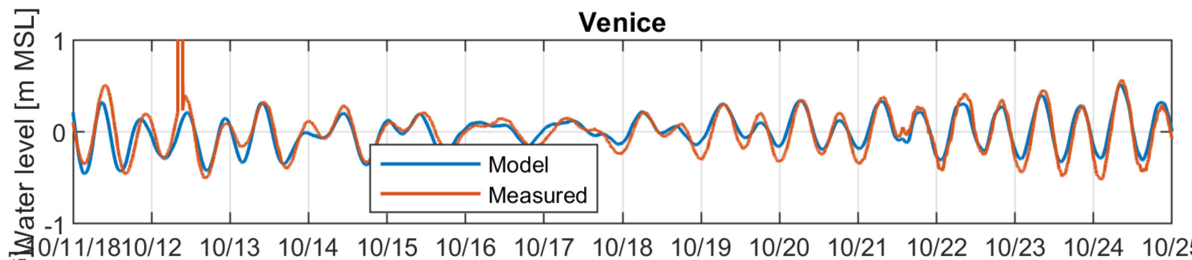


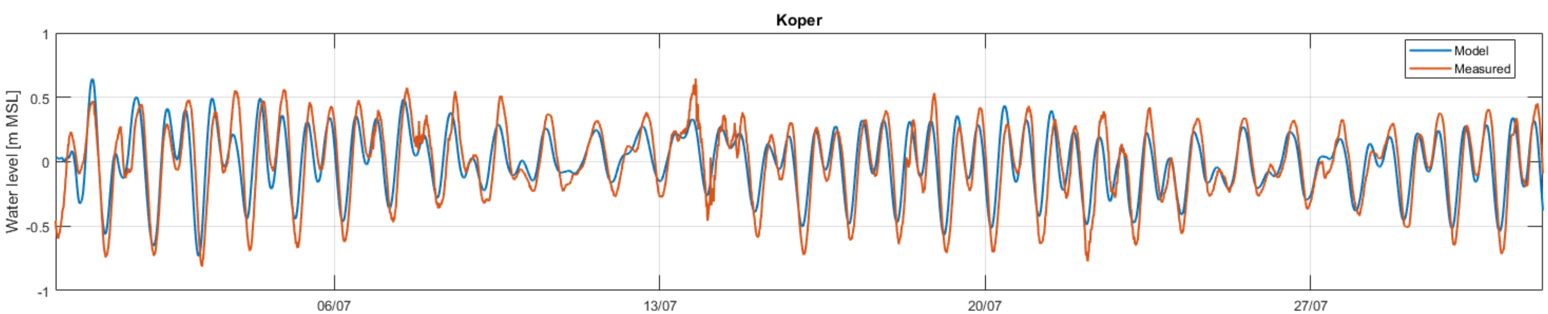
Two seasons: winter and summer

- Winter season: October 2018
  → calibration hydrodynamics (water levels, currents)
- Summer season: July 2008
  → validation stratification (S, T)

Hydrodynamic calibration – Far field Adriatic model





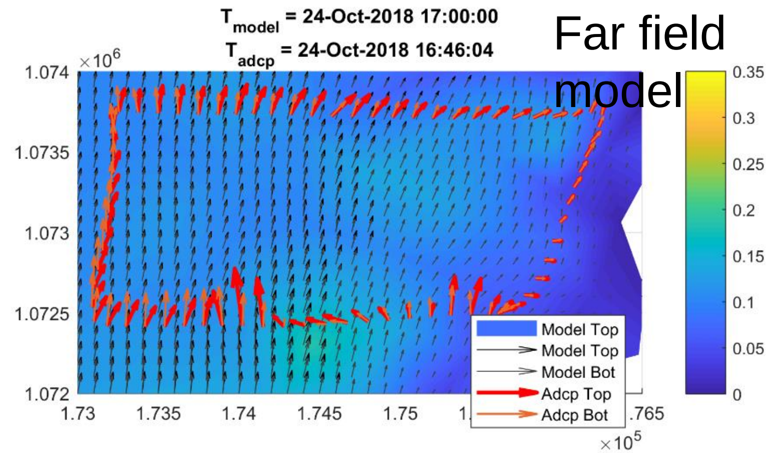


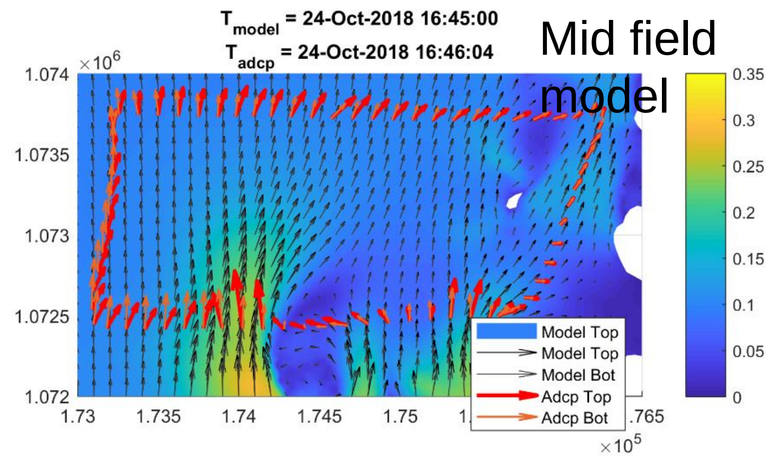
Hydrodynamic calibration – currents

- Currents to be checked in mid field mo (importance of features)

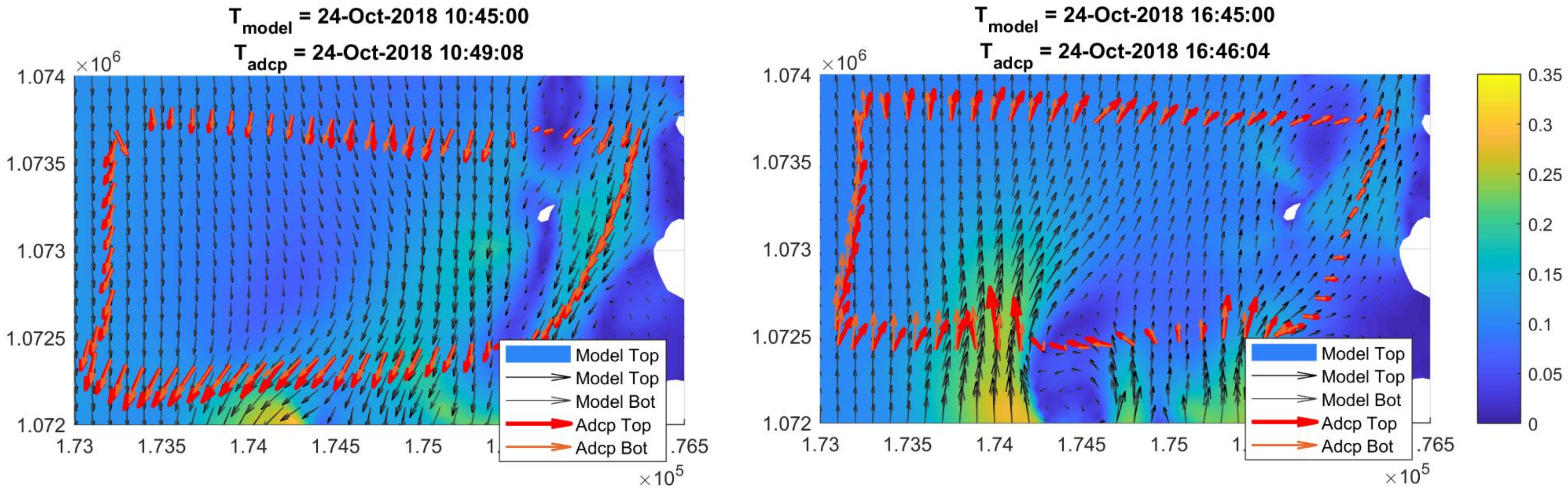
- Re-analysis survey data
- Check on wind conditions

- Current patterns
- Comparison current fields shows good



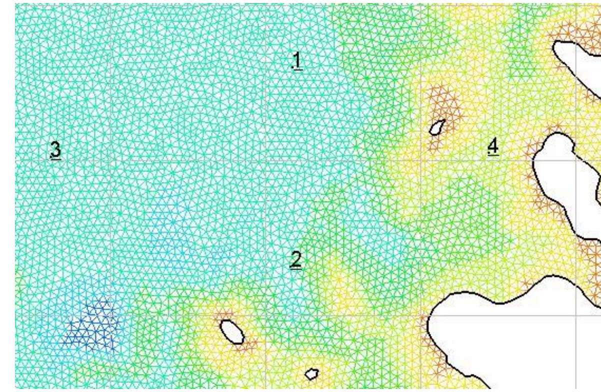


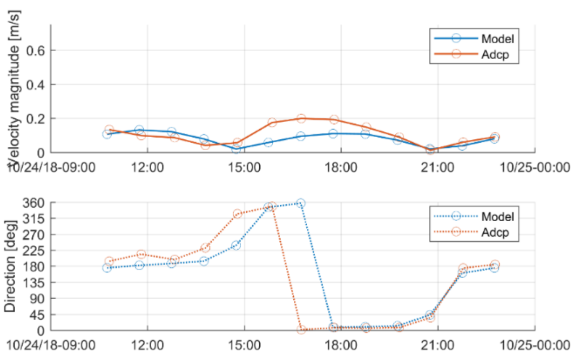
Hydrodynamic calibration - currents

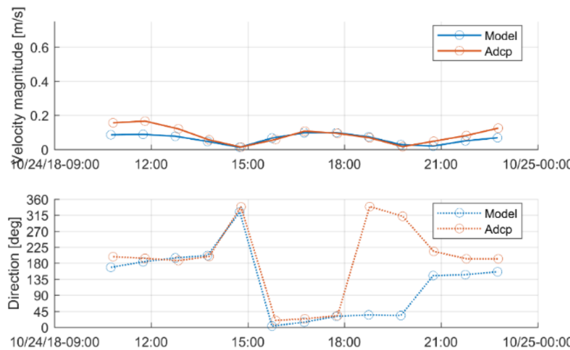


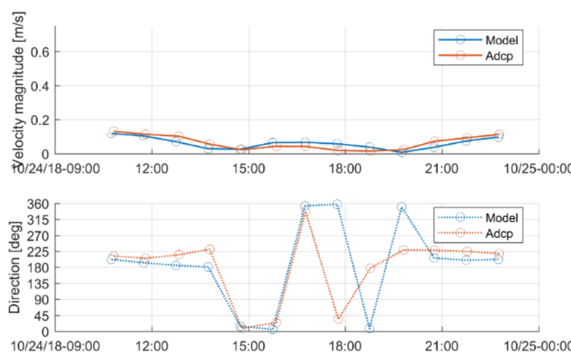
IMDC

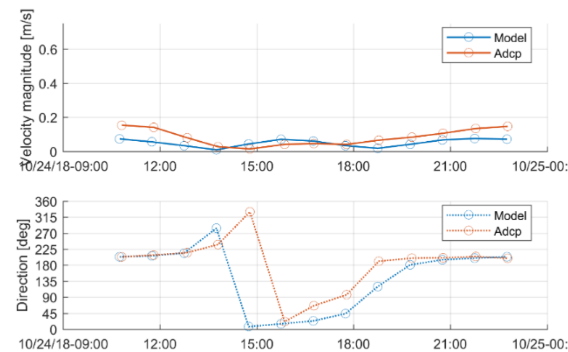
Hydrodynamic calibration – currents (mid field model)









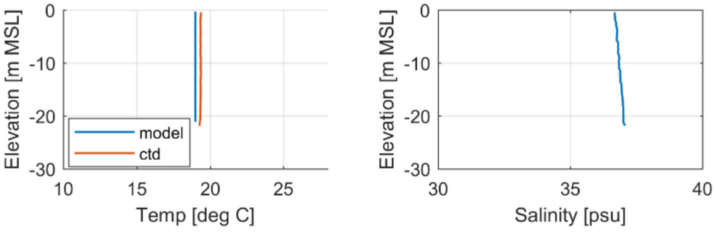


IMDC

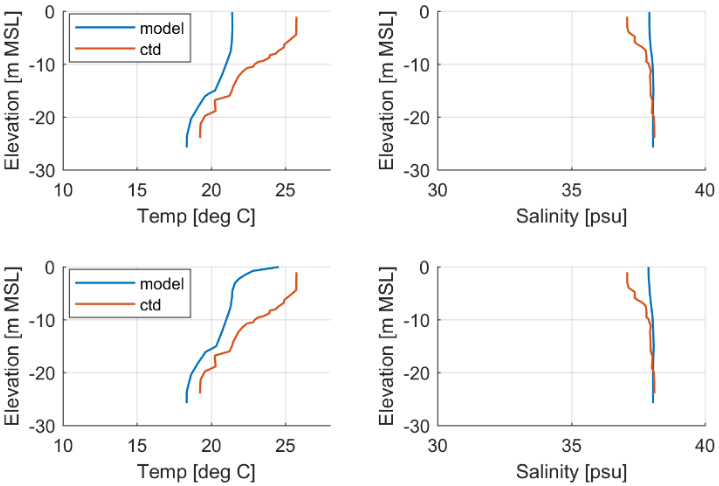
Validation stratification

Winter – well mixed

(CTD survey)



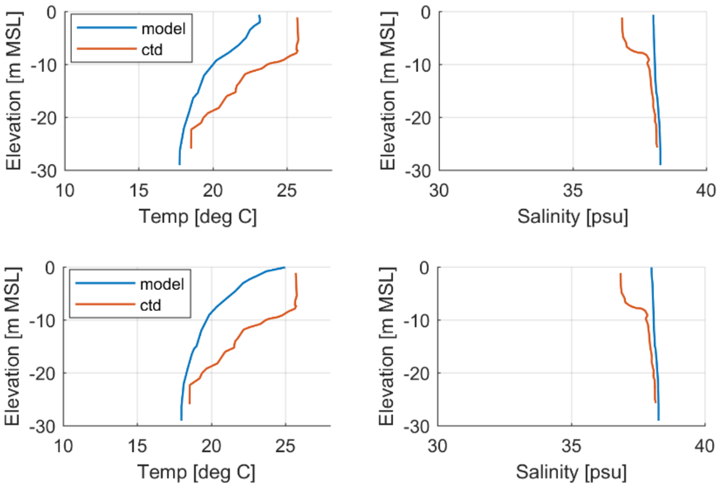
S1 station



17/07/2008 06:00

17/07/2008 18:00

S2 station



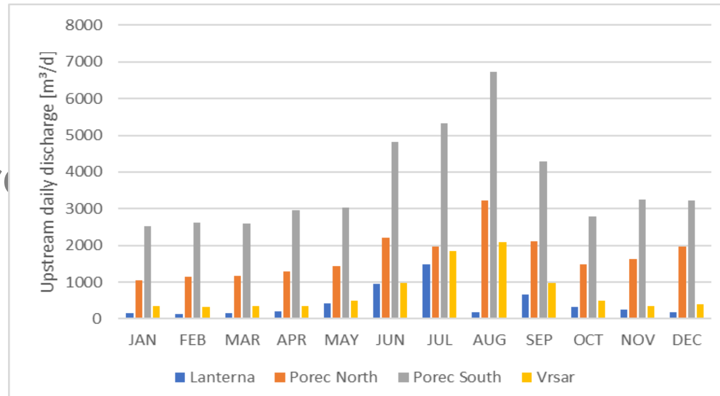
Summer – stratification potential *(CTD literature)*

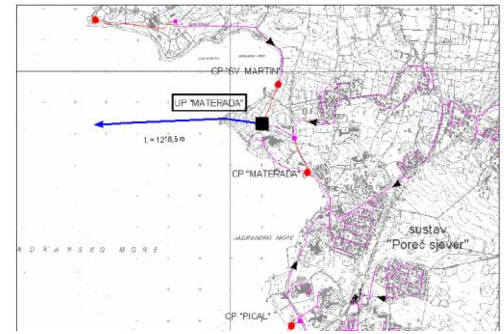
Water quality calibration

- Dataset
  - Outfall data
  - Water quality measurements
  - Decay experiments
- Modelsetup
  - Near field model
  - Mid field model
- Results

Water quality calibration

- Outfall data
- Water quality measur
- Decay experiments

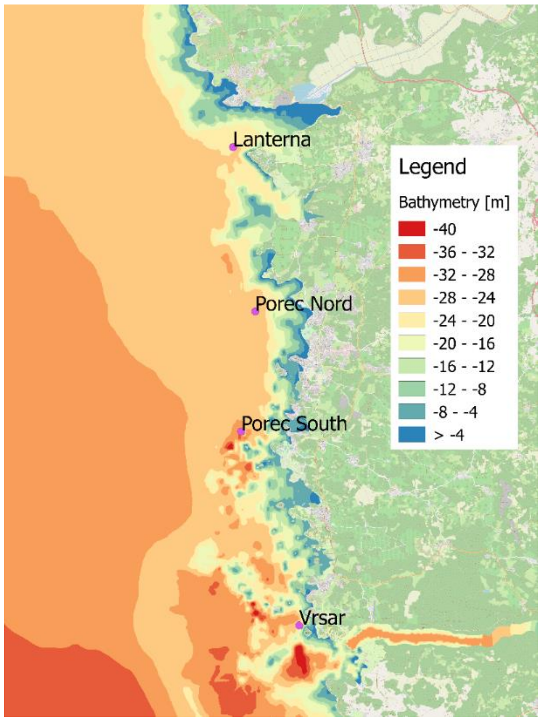


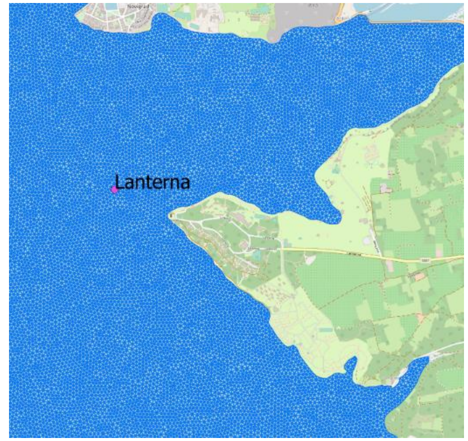


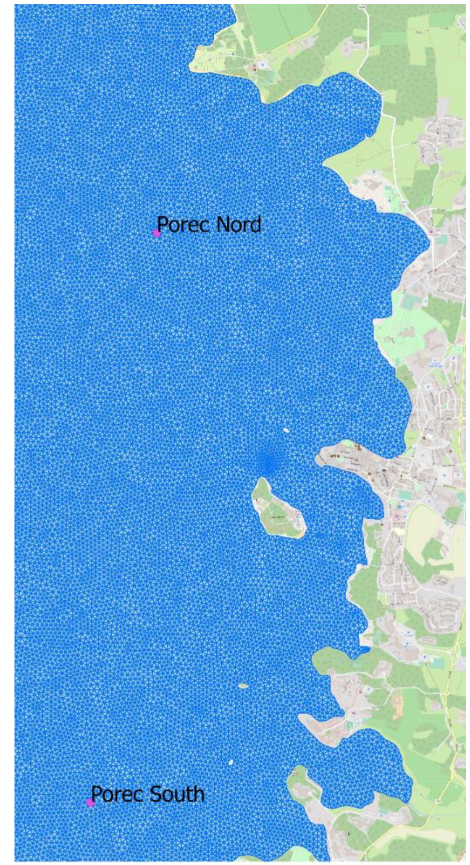
Outfall	Type	L to diffusor	L diffusor	Number of opening	D opening	Qs,max	V collector	Interval winter	Interval summer
Lanterna	Diffusor	500	86	13	0.1	0.11	50	480	92
Cervar	Single pipe	300	-	1	0.315	0.075			
Porec North	Diffusor	900	100	20	0.1	0.11	50	52	30
Porec South	Diffusor	800	90	20	0.1	0.14	50	26	13
St Nicholas	Single pipe	300	-	1	0.5	0.002			
Vrsar	Single pipe	488	-	1	0.5	0.075	25	103	22
Coversada	Single pipe	110	-	1	0.1	0.002			

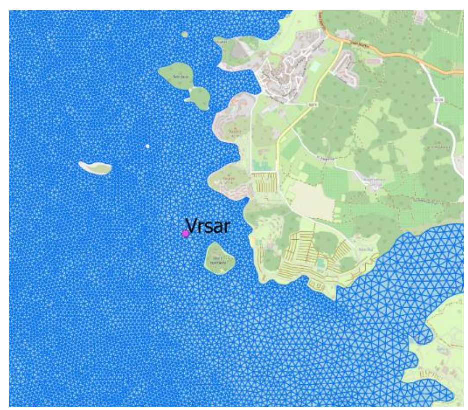
IMDC

Model setup – Mid field model





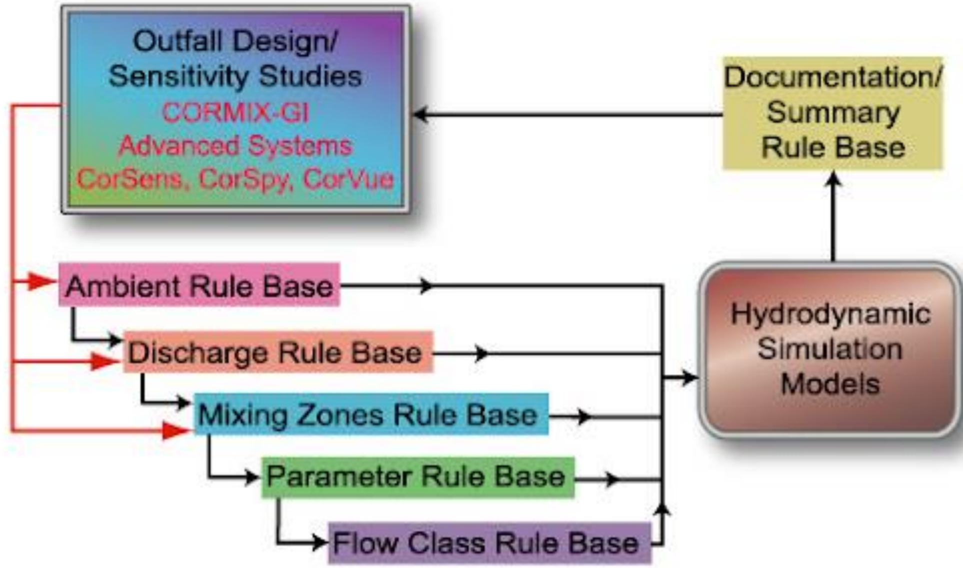


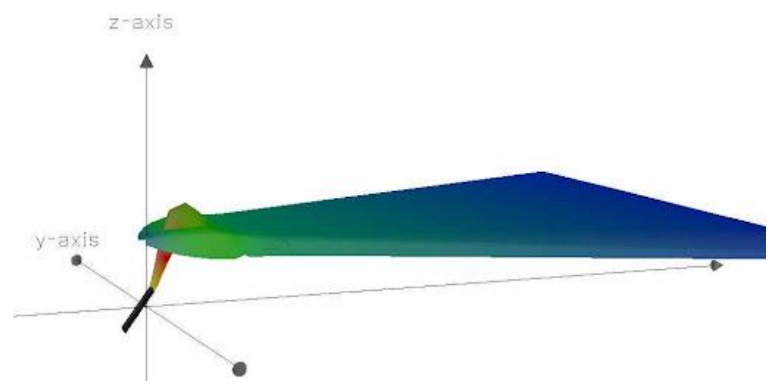


IMDC

Near field model: Cormix

- Cormix:
  - Software for near field modelling
  - Based on :
    - rule based system
    - simplified flow model (integral jet and plume models)
    - can take rising/falling of plumes (due to density difference) into account
    - does not take into account bathymetry
    - uses simplified background flow/stratification

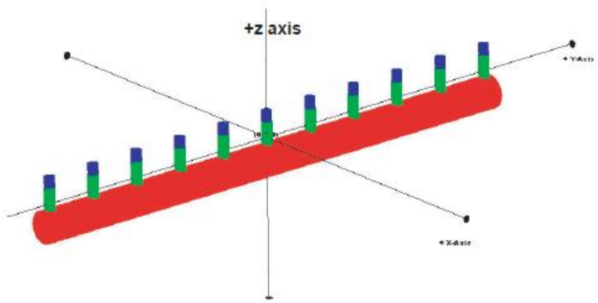


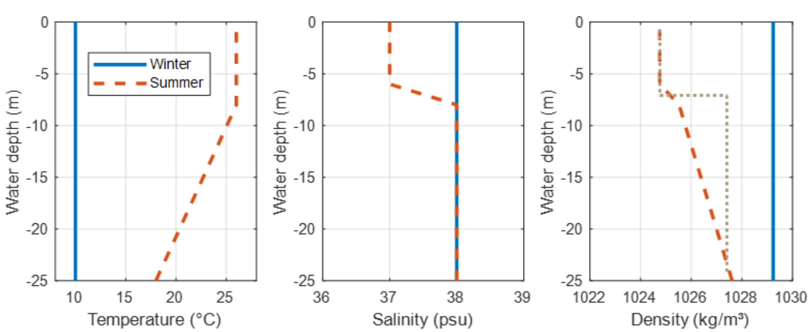


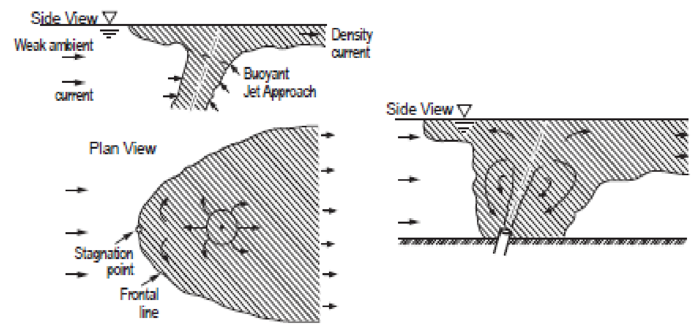
IMDC

Water quality calibration

- Near field modelling of effluent with Cormix

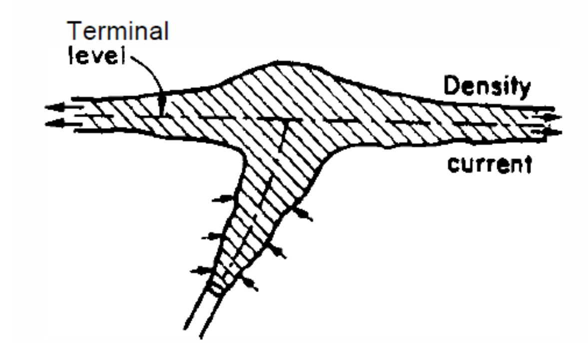






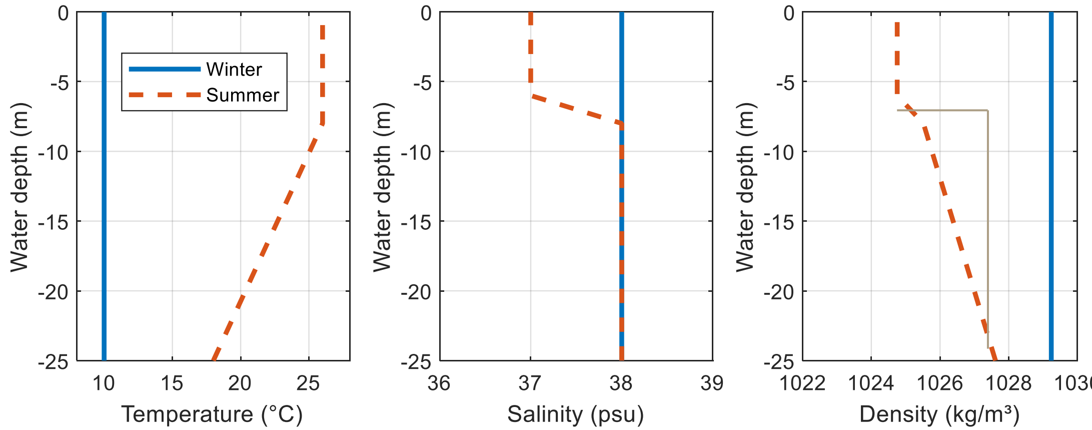
b) Surface Impingement with Buoyant Upstream Spreading

d) Surface Impingement with Local Vertical Mixing. Buoyant Upstream Spreading and Restratifications



IMDC

Near field model: Inputs Porec North



- Ambient density
  - Winter (cst)
  - Summer (stratified profiel - jump)
- Effluent density (assumption same T, S=0)
  1. Winter = 999,6 kg/m³ (discharged in 1029,2 kg/m³)
  2. Summer = 997 kg/m³ (discharged in 1027,6 kg/m³)
- Water depth = -25 m, 2000 m from shore
- Ambient velocities:
  1. 0,1 m/s
  2. 0,3 m/s
- No wind so far
- Diffuser and max discharge as in table (assumption opening 0,5m above bed)
- Assuming no decay

4 cases:

1. Winter – 0,1 m/s
2. Winter – 0,3 m/s
3. Summer – 0,1 m/s
4. Summer – 0,3 m/s

IMDC

Near field model results

- Case 1 – winter 0,1 m/s

```
MIXING ZONE EVALUATION (hydrodynamic and regulatory summary):

-----------------------------------------------------------------------------
X-Y-Z Coordinate system:
  Origin is located at the BOTTOM below the port/diffuser center:
    2050 m from the left bank/shore.
  Number of display steps NSTEP = 400 per module.
-----------------------------------------------------------------------------
NEAR-FIELD REGION (NFR) CONDITIONS :
Note: The NFR is the zone of strong initial mixing.  It has no regulatory
  implication.  However, this information may be useful for the discharge
  designer because the mixing in the NFR is usually sensitive to the
  discharge design conditions.
  Pollutant concentration at NFR edge  c = 0.0535 bacteria-counts
  Dilution at edge of NFR              s = 1869.3
  NFR Location:                        x = 35.71 m
    (centerline coordinates)           y = 0 m
                                       z = 25 m
  NFR plume dimensions:  half-width (bh) = 64.72 m
                          thickness (bv) = 21.66 m
  Cumulative travel time:       326.7551 sec.
```

- Case 2 – winter 0,3 m/s

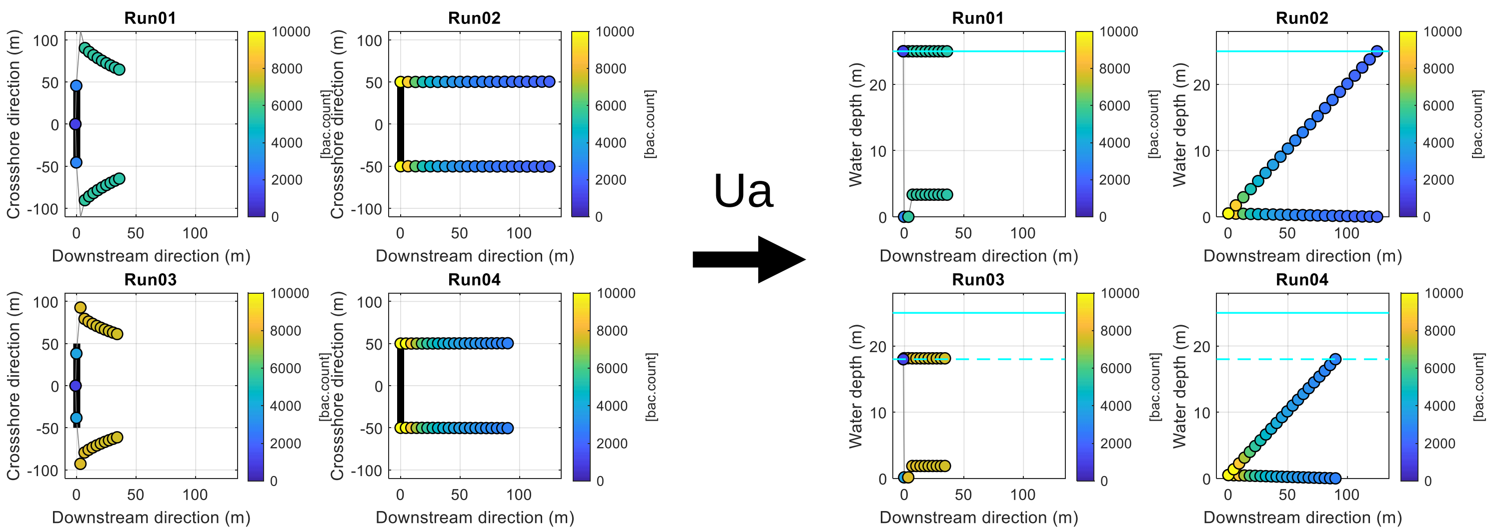
```
MIXING ZONE EVALUATION (hydrodynamic and regulatory summary):

-----------------------------------------------------------------------------
X-Y-Z Coordinate system:
  Origin is located at the BOTTOM below the port/diffuser center:
    2050 m from the left bank/shore.
  Number of display steps NSTEP = 400 per module.
-----------------------------------------------------------------------------
NEAR-FIELD REGION (NFR) CONDITIONS :
Note: The NFR is the zone of strong initial mixing.  It has no regulatory
  implication.  However, this information may be useful for the discharge
  designer because the mixing in the NFR is usually sensitive to the
  discharge design conditions.
  Pollutant concentration at NFR edge  c = 0.0198 bacteria-counts
  Dilution at edge of NFR              s = 5039.6
  NFR Location:                        x = 125 m
    (centerline coordinates)           y = 0 m
                                       z = 25 m
  NFR plume dimensions:  half-width (bh) = 50.40 m
                          thickness (bv) = 25 m
  Cumulative travel time:       826.7854 sec.
-----------------------------------------------------------------------------
```


IMDC

Near field model input for mid field model

Run	Dilution	Xc	Yc	Zc	BH (1/2) (top hat)	BV (full) (top hat)	TT (min)	Remark
Parameters input		X=Xc	Y=Yc	Z=Zc-BV/2?	L=BH of BH*2?	B=BV/2?		Phi, Theta ? Fractions (next to bacteria, T, S?)
01 – W+0.1m/s	1869	36	0	25	64,7	21,7	5,5	Buoyant plume, uniform C
02 – W+0.3m/s	5040	125	0	25	50,4	25	13,8	Fully vertically mixed, uniform C
03 – S+0.1m/s	1329	34	0	18	61,3	16,3	5,2	Trapped, buoyant plume, uniform C
04 – S+0.3m/s	3629	90	0	18	50,4	18	9,9	Trapped + fully mixed in lower layer, uniform C



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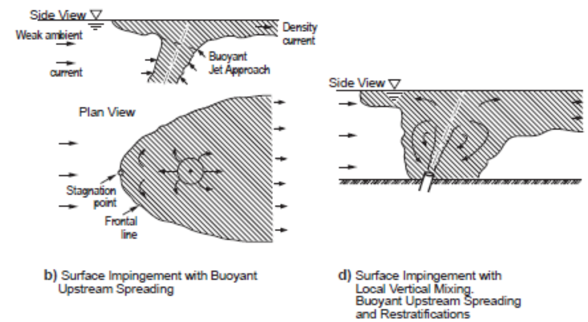
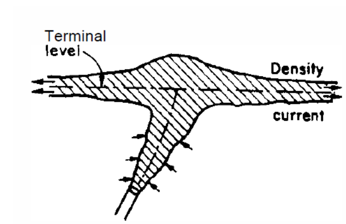
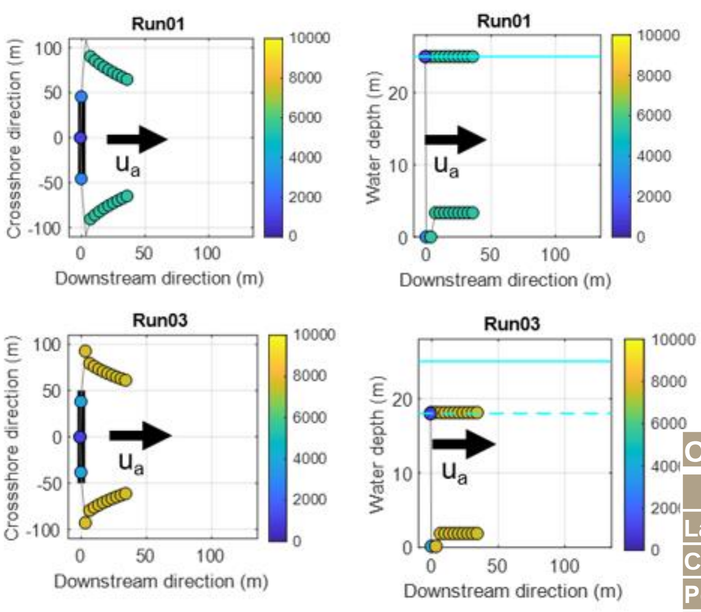
Water quality calibration

- Near field modelling of effluent with Cor





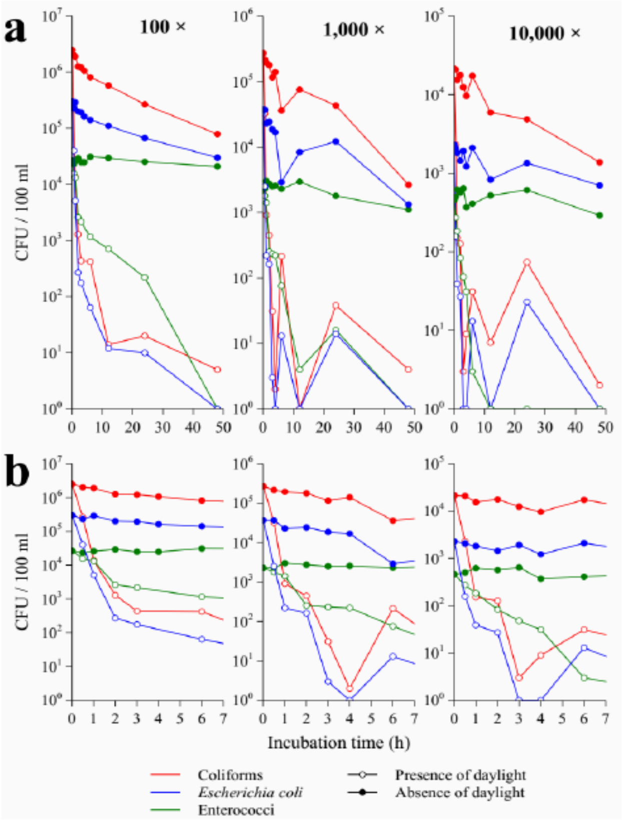


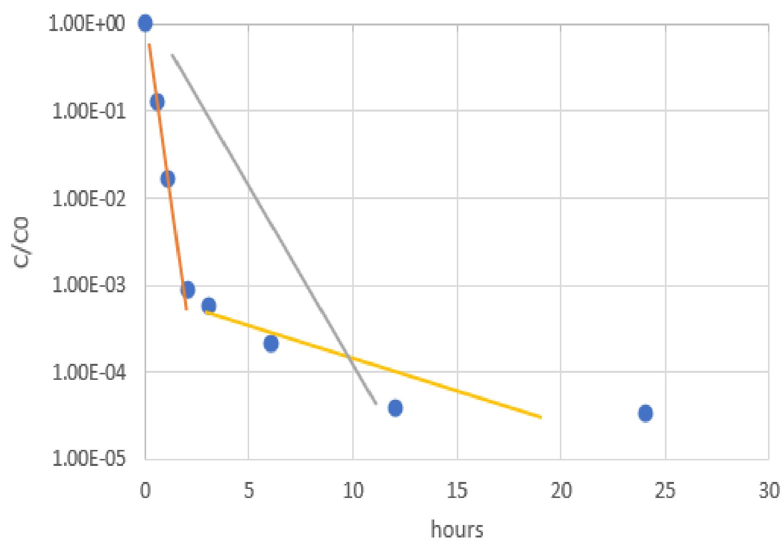
Example Porec North

Outfall	Winter		Summer	
	Horizontal width	Vertical extend	Horizontal width	Vertical extend
Lanterna	110	-24 to 0 m	45	-17 to -6 m
Cervar	440	-1 to 0 m	520	-7 to -6 m
Poreč North	60	Sea bed to 0 m	50	Sea bed to -6 m
Poreč South	67	-22 to 0 m	64	-24 to -6 m
St Nicholas	10	-10 to 0 m	10	-16 to -6 m
Vrsar	39	-3 to 0 m	34	-8 to -6 m
Coversada	5	-5 to 0 m	3	-9 to -6 m

IMDC

Water quality calibration (decay experiments)



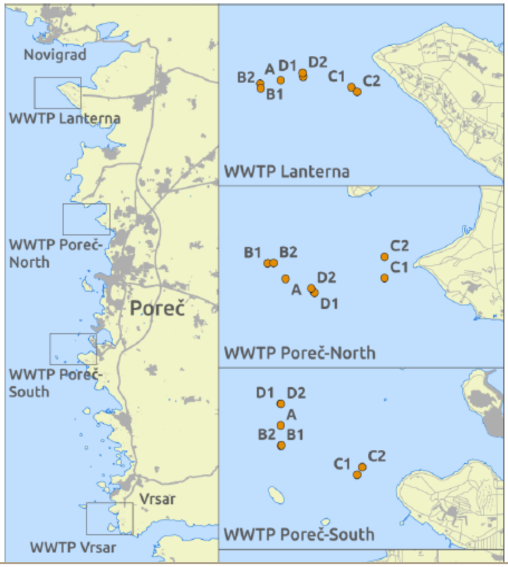


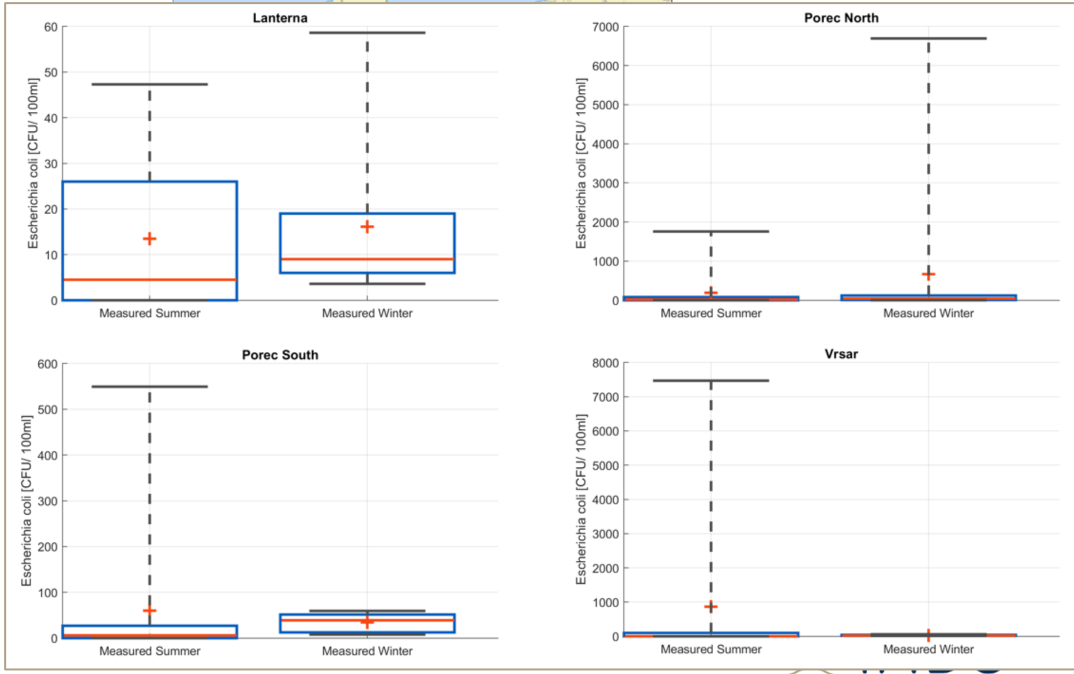
Parameter	Primary decay rate (T_{90}-value) [h]	Secondary decay rate (T_{90}-value) [h]	Combined decay rate (T_{90}-value) [h]
ECOLI (day)	1	18	9.5
IE (day)	3	18	10.5
ECOLI (night)	48	60	54
IE (night)	48	120	84

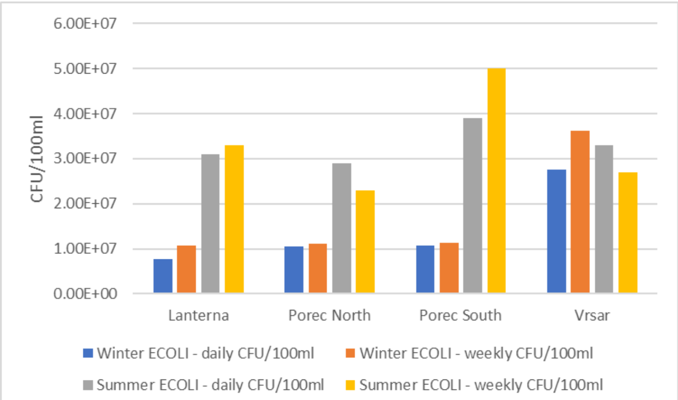
Water quality calibration

- ater quality measurements
  - FB in the sewage system (source)
  - FB in the coastal system (calibration)
  - *(Temperature, Salinity)*
- Decay experiments

Concentrations at sea to calibrate the model

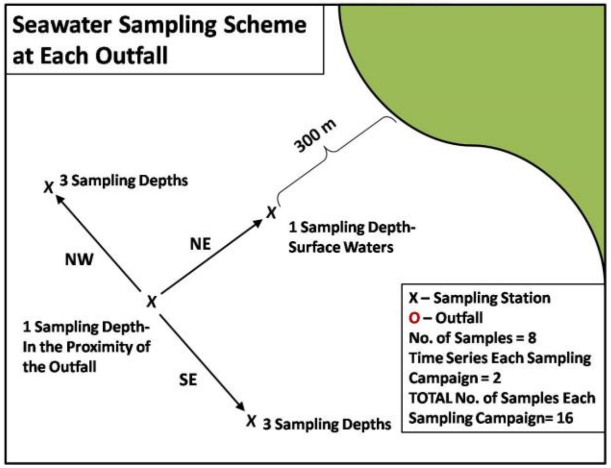






Concentrations in sewage system as input

Water quality measurement campaigns



- Measurements of concentrations of EC in winter and summer and decay rate experiment in summer by IRB
- Goals:
  - Support model setup
  - Calibration water quality model
- Status:
  - Finished

Outfall	Collection Tank Range EC (cfu/100ml)	Sea Range EC (cfu/100ml)
Lanterna	4 – 14 e+6	3 – 64
Porec North	4 – 21 e+6	1 – 9400
Porec South	8 – 13 e+6	7 – 60
Vrsar	11 – 61 e+6	13 – 62

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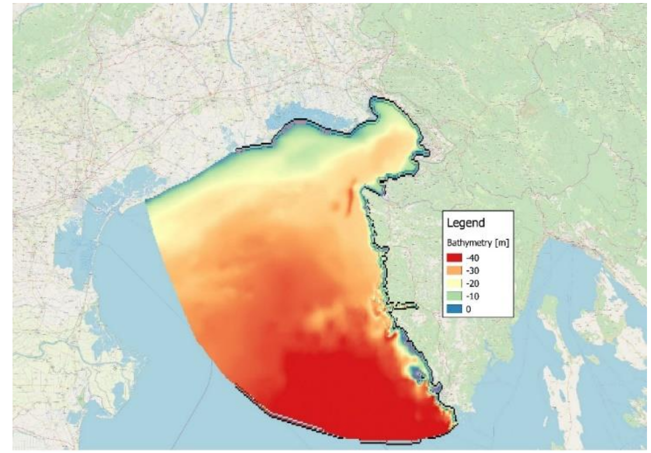
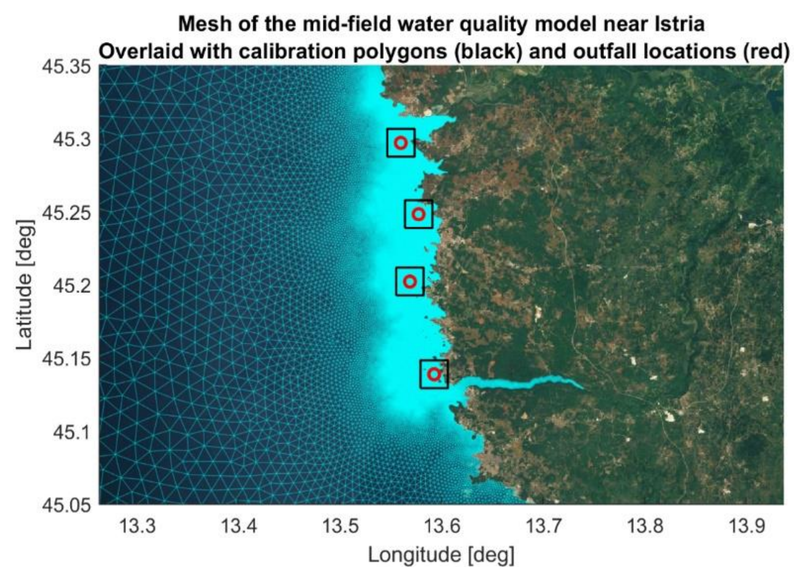
Water quality calibration

- Mid field model – Istrian coast
- Escherichia coli (ECOLI) and Enterococci (IE) bacteria

- Searching for optimal settings for the water quality model – running different simulations

- Winter (Jan 2019) and summer (July 2019)



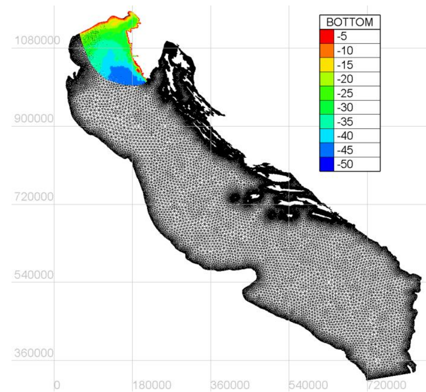


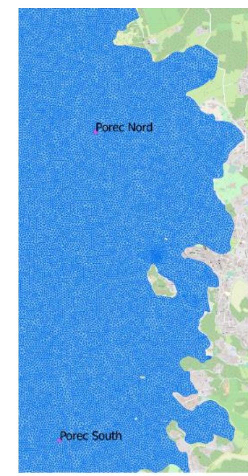
IMDC

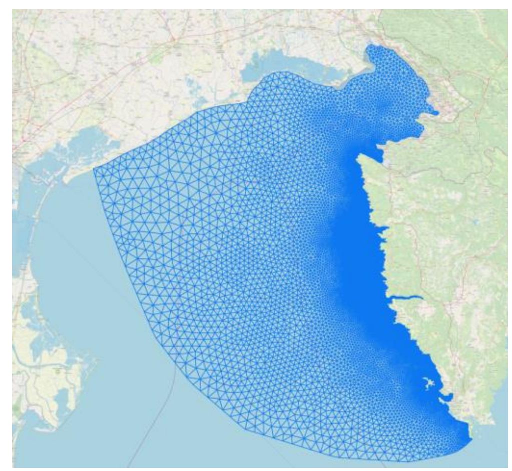
- Focus on representing typical

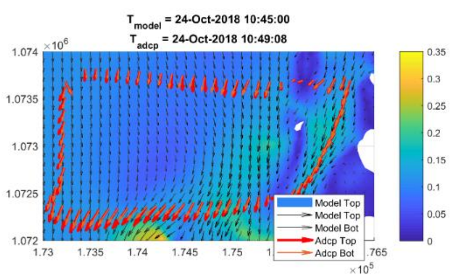
Water quality calibration

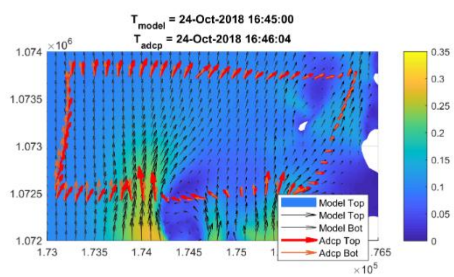
- Module for introducing the bacteria discharge coupling the near field and mid field model
- Implementation of the decay rate of the bacteria











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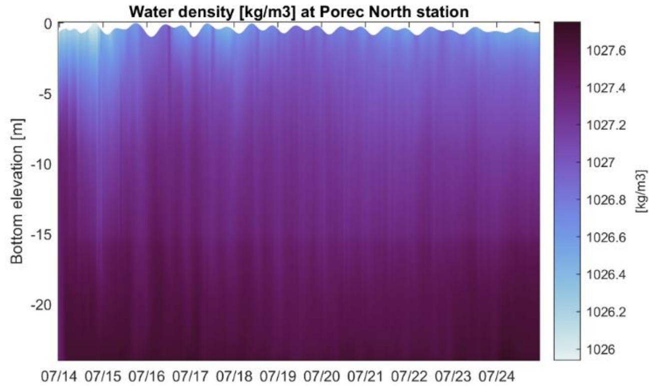
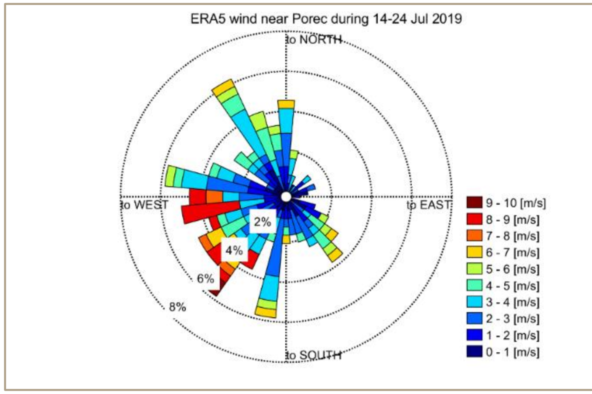
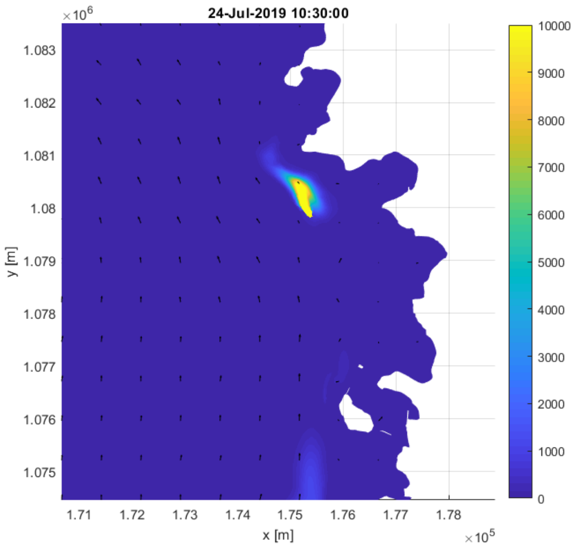
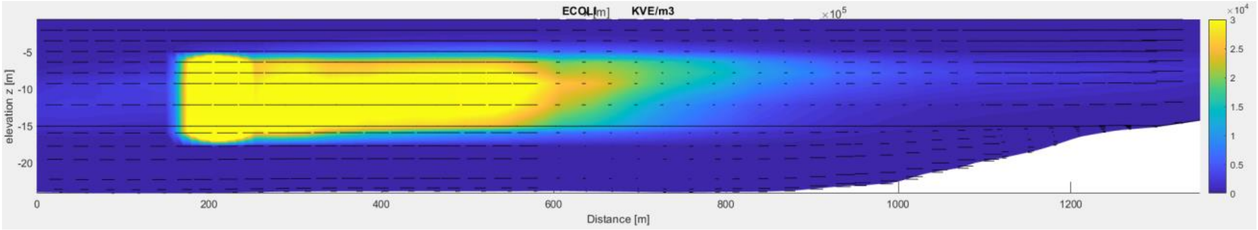
Water quality calibration: model results

- Summer









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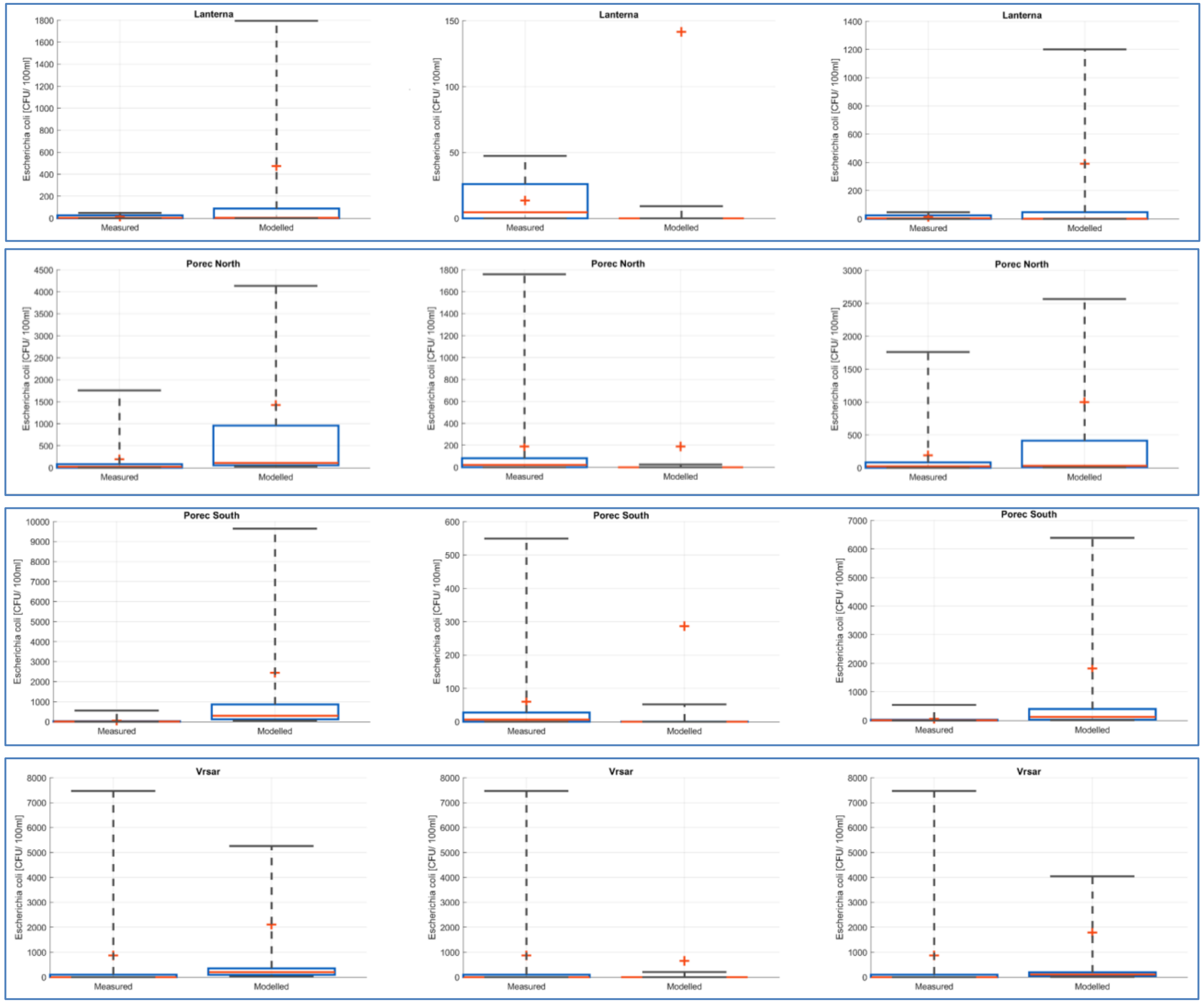
Water quality calibration: comparison with observations

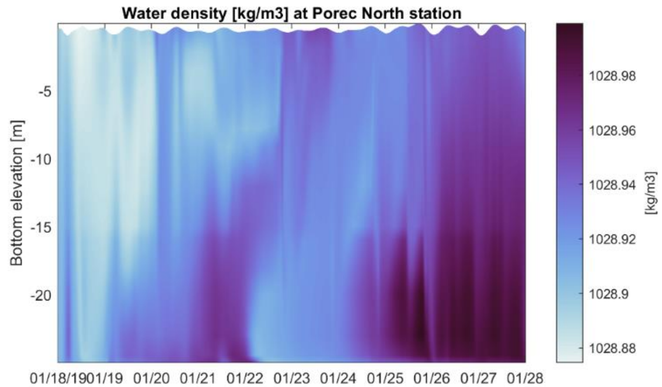


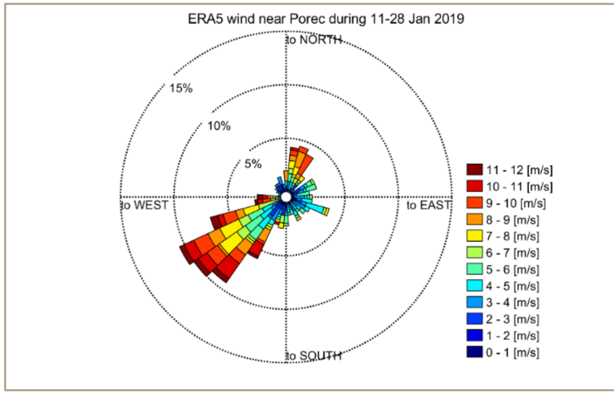
- 4 outfalls
- Measured vs modelled concentration (CFU/100mL)
- Three decay sets tested
  1. Primary
  2. Secondary
  3. Combined
- Best behaviour with combined set

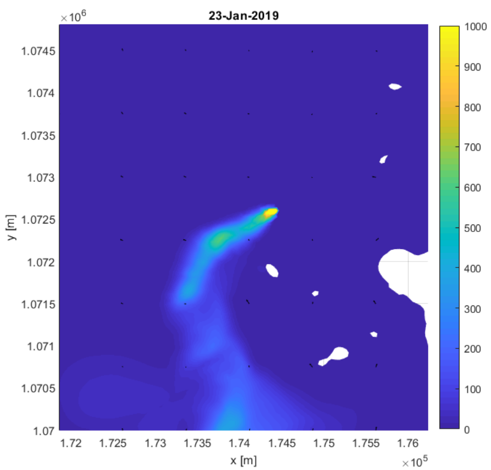
IMDC

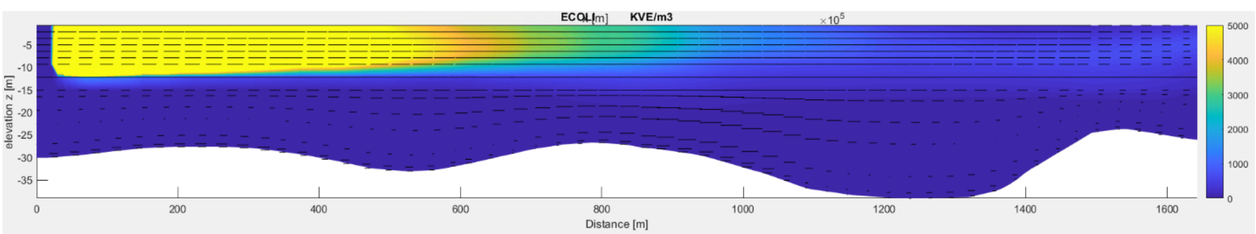
Water quality calibration

- Winter









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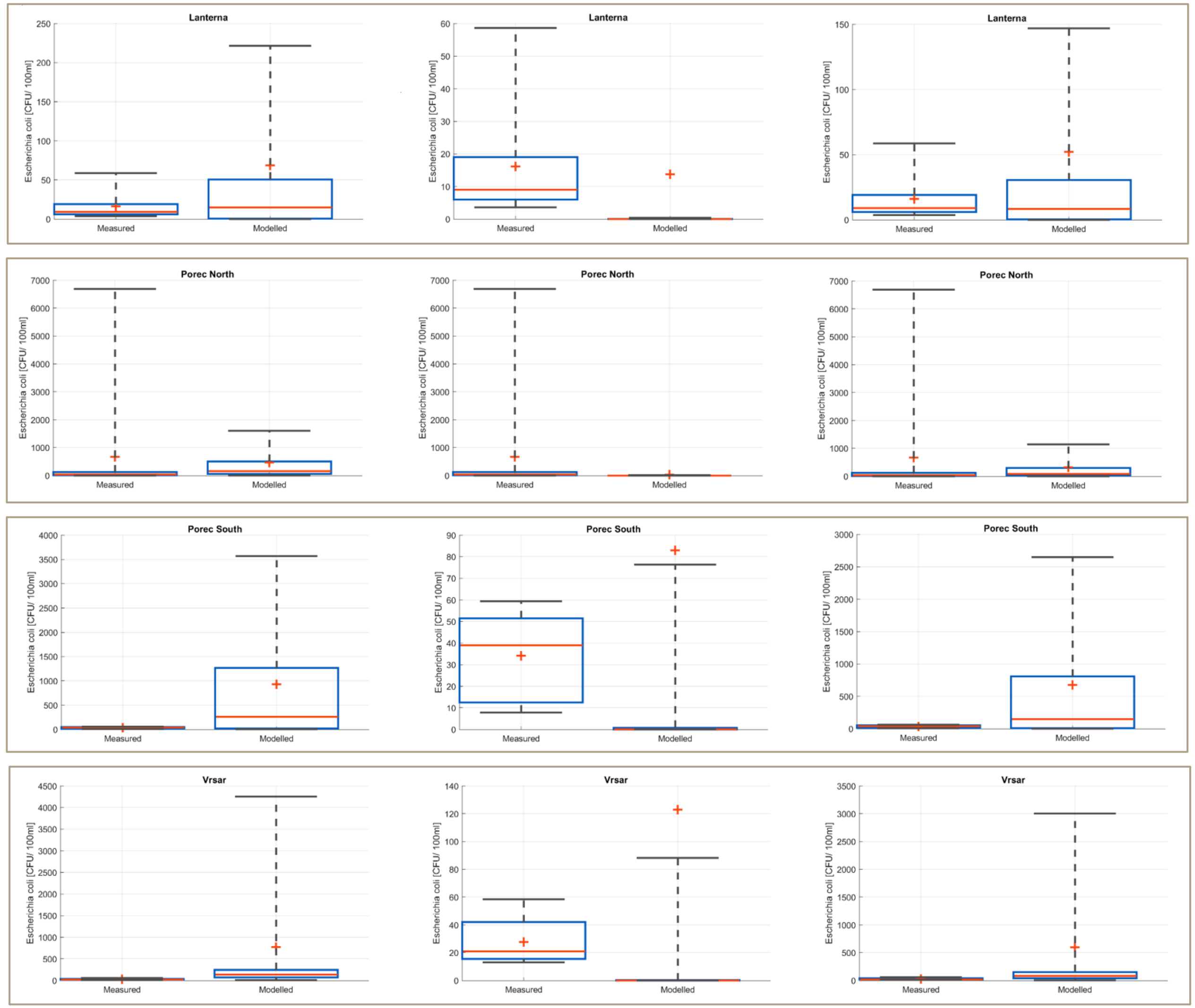
Water quality calibration

- 4 outfalls
- Measured vs modelled concentration (CFU/100mL)
- Three decay sets tested
  1. Primary
  2. Secondary
  3. Combined
- **Best behaviour with combined set**



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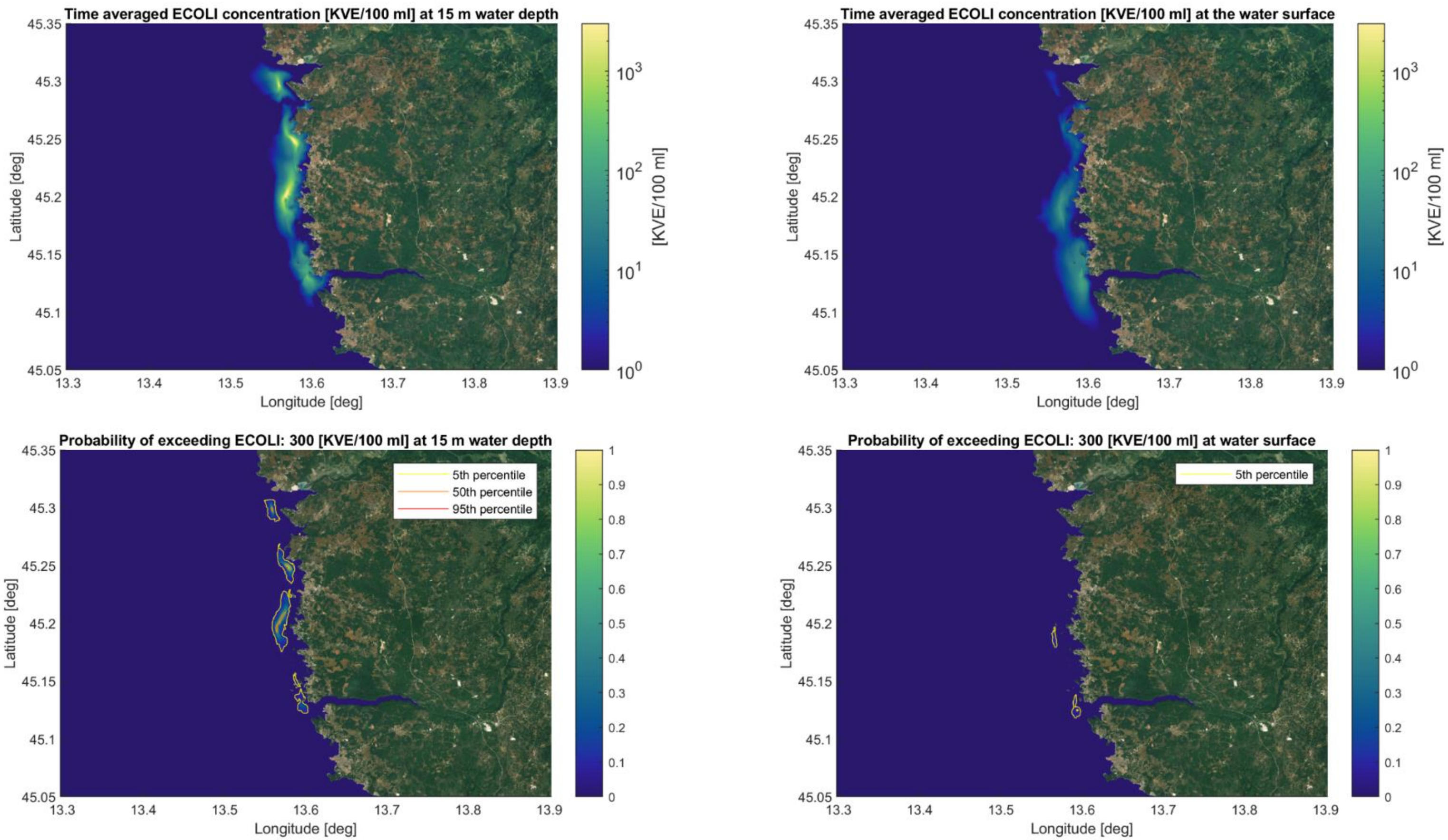
Assessing situation without WWTP – stratified conditions (summer)



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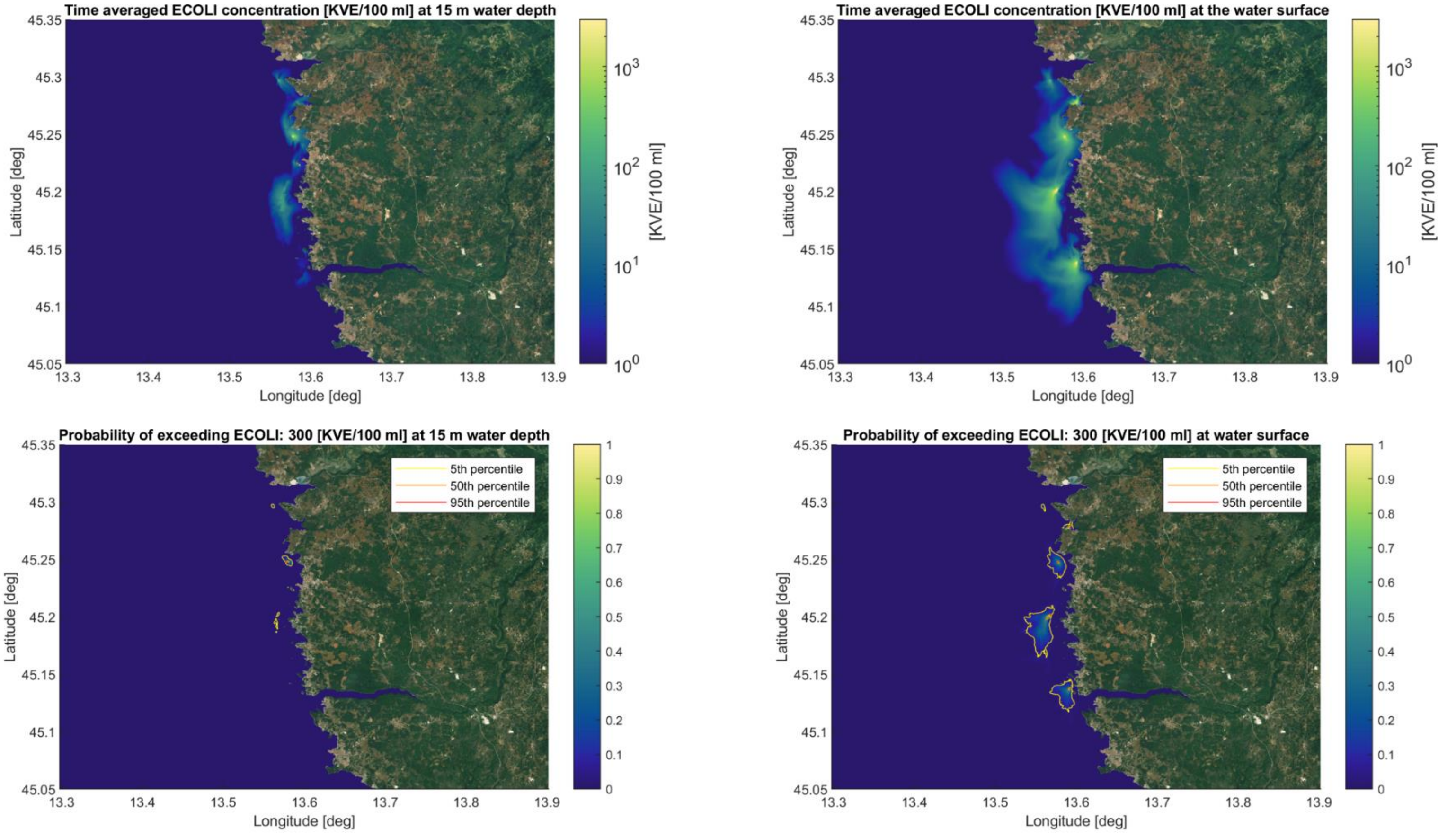
Assessing situation without WWTP – mixed conditions (winter)



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Annex B Review of the course

IMDC

Evaluation of the TELEMAC course

1 Quality of the training

What is your general opinion on (the quality of) the training

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ● 10

2) Was the course conform the program?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ● 10

3) Program of the course:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ● 10

4) Teacher(s):

Did the teacher(s) match your expectations regarding communication, way of teaching, ...?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9 ○ 10

5) Organisation:

You can give a general score on the organisation: e.g. communication beforehand, was the course material available during the training, quality of the accommodation, visibility of the presented material.

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9 ○ 10

6) Course material:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ● 10

7) Technology and knowledge:

Did the course meet your expectations? Did it provide new insights?

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ● 10

8) Do you any remarks or suggestions on the course?

....

....

IMDC

Evaluation of the TELEMAC course

1 Quality of the training

What is your general opinion on (the quality of) the training

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

2) Was the course conform the program?

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

3) Program of the course:

○	○	○	○	○	○	○	●	○	○
1	2	3	4	5	6	7	8	9	10

4) Teacher(s):

Did the teacher(s) match your expectations regarding communication, way of teaching, ...?

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

5) Organisation:

You can give a general score on the organisation: e.g. communication beforehand, was the course material available during the training, quality of the accommodation, visibility of the presented material.

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

6) Course material:

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

7) Technology and knowledge:

Did the course meet your expectations? Did it provide new insights?

○	○	○	○	○	○	○	●	○	○
1	2	3	4	5	6	7	8	9	10

8) Do you any remarks or suggestions on the course?

....

....

IMDC

Evaluation of the TELEMAC course

1 Quality of the training

What is your general opinion on (the quality of) the training

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

2) Was the course conform the program?

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

3) Program of the course:

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

4) Teacher(s):

Did the teacher(s) match your expectations regarding communication, way of teaching, ...?

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

5) Organisation:

You can give a general score on the organisation: e.g. communication beforehand, was the course material available during the training, quality of the accommodation, visibility of the presented material.

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

6) Course material:

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

7) Technology and knowledge:

Did the course meet your expectations? Did it provide new insights?

○	○	○	○	○	○	○	○	○	●
1	2	3	4	5	6	7	8	9	10

8) Do you any remarks or suggestions on the course?

....

....

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 17 – dio3/4

EDUKACIJA DJELATNIKA: UZORKOVANJE I EKSPERIMENTALNE METODE

Veljača 2022

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IZVJEŠĆE 17 – dio3/4

EDUKACIJA DJELATNIKA: UZORKOVANJE I EKSPERIMENTALNE METODE

20 veljače 2022

mr.sc. Božidar Deduš, dipl. ing.
Ovlaštenik Zajednice izvršitelja
Proning DHI d.o.o.

17 veljače 2022

prof.dr.sc. Damir Brdjanovic, dipl.ing.
Voditelj stručnog tima
IHE Delft

United Nations Educational, Scientific and Cultural Organization
IHE DELFT
Institute for Water Education under the auspices of UNESCO

IHE Delft

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Prehrambeno - biotehnološki fakultet
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Investitor:	Hrvatske vode, Ulica grada Vukovara 210, HR-10000 Zagreb
Projekt:	Izvještaj br. 17 dio 3 (od 4): Edukacija djelatnika
Vrsta projekta:	Stručni projekt
Oznaka projekta:	SP-2022-17-3/4

Izradili: Prof. dr. sc. Marin Matošić

Doc. dr. sc. Josip Ćurko

Vlado Crnek, mag. ing. agr.

Ovlaštenik zajednice izvršitelja: Mr. sc. Božidar Deduš dipl. ing., Proning DHI d. o. o.

Voditelj stručnog tima: Prof. dr. sc. Damir Brđanović, IHE Delft

URBROJ:	251-69-01-22-22
KLASA:	303-02/22-01/01
Mjesto i datum:	Zagreb, 16 veljače 2022.

Sveučilište u Zagrebu
Prehrambeno-biotehnološki fakultet
Laboratorij za tehnologiju vode
Pierottijeva 6, HR-1000 Zagreb

Sadržaj:

Sveučilište u Zagrebu
Prehrambeno-biotehnološki fakultet
Laboratorij za tehnologiju vode
Pierottijeva 6, HR-1000 Zagreb

1. Uvod

Temeljem potpisanog Podizvoditeljskog ugovora između PRONING DHI d.o.o. i Prehrambeno-biotehnološkog fakulteta Sveučilišta u Zagrebu, izvršili smo ugovorenu uslugu edukacije djelatnika poduzeća Usluga Poreč d.o.o. o radu četiri novoizgrađena uređaja za pročišćavanje otpadnih voda grada Poreča. Edukacija je održana 20 siječnja 2022. u prostoru novoizgrađenog UPOV-a Poreč Jug, a proveli su je djelatnici Laboratorija za tehnologiju vode Prehrambeno-biotehnološkog fakulteta Sveučilišta u Zagrebu uz stručnu pomoć prof. dr. sc. Damira Brđanovića. Za potrebe edukacije korištena je laboratorijska oprema Prehrambeno-biotehnološkog fakulteta Sveučilišta u Zagrebu donesena za tu svrhu iz Zagreba. Edukaciji su prisustvovali:

- Siniša Pilat, Rukovoditelj sektora prikupljanja i odvodnje otpadnih voda
- Zoran Ardalić, Rukovoditelj sektora razvoja i investicija
- Ivan Banić, Voditelj kanalizacije
- Mario Laković, Pomoćnik voditelja uređaja

Na slikama 1 i 2 su prikazani sudionici i lokacija edukacije.

Slika 1. Edukacija u prostorijama UPOV-a Poreč Jug

Slika 2. Sudionici edukacije

U sklopu edukacije djelatnici Usluge Poreč d.o.o. upoznali su se sa sljedećim temama u tehnologiji obrade otpadnih voda:

1. Grupe mikroorganizama od interesa u biološkoj obradi otpadnih voda
2. Provedba testova aktivnosti mikroorganizama
3. Kemijske analize vode i aktivnog mulja
4. Mikroskopiranje aktivnog mulja

U nastavku su detaljnije opisane teme edukacije i njihov sadržaj kako je bio prezentiran sudionicima.

2.1. Grupe mikroorganizama od interesa u biološkoj obradi otpadnih voda

U sklopu ove teme sudionici edukacije su upoznati s različitim grupama mikroorganizama čija je aktivnost i prisutnost u novoizgrađenim UPOV-ima nužna za uspješnu obradu otpadnih voda.

Obični heterotrofni organizmi su glavna grupa mikroorganizama koja provodi većinu razgradnje organske i suspendirane tvari iz otpadne vode. Zbog toga je važno znati njihove karakteristike kao što su su stupanj konverzije supstrata (otpadnih biorazgradivih tvari) u biomasu mikroorganizama

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(aktivni mulj) iz kojega znamo koliko će nastati aktivnog mulja u procesu obrade te specifična brzina odumiranja iz koje znamo koliko će mikroorganizama odumrijeti u procesu obrade. Naglasak u opisu metabolizma ove grupe mikroorganizama stavljen je na njihovu sposobnost da potpuno razgrade organske tvari u prisutnosti kisika, ali i nitrata, ako kisik nije prisutan, pri čemu njihova sposobnost da razgrađuju organske tvari u prisutnosti nitrata čini esencijalni preduvjet za uspješno biološko uklanjanje dušika jer se nitrati u procesu prevode u plinoviti dušik koji kao takav izlazi iz UPOV-a čime se postiže eliminacija dušika iz otpadne vode. Proces upotrebe nitrata u razgradnji organske tvari naziva se denitrifikacija.

Grupa mikroorganizama koja nitrifikacijom proizvodi nitrate iz amonija i koja se naziva nitrificirajući mikroorganizmi bila je također važan dio u edukaciji. U sklopu opisa ove grupe naglašeno je da su oni obligatni aerobi koji trebaju kisik za svoj rast i provedbu nitrifikacije. Također, polaznici su upoznati s činjenicom da su nitrificirajuće bakterije autotrofne i same proizvode potrebne organske komponente za svoj rast što čini njihov rast značajno sporijim od brzine rasta heterotrofa. Zbog toga u UPOV-ima treba održavati veću starost mulja tj. zadržavati mulj u uređaju dovoljno dugo da se u njemu razvije stabilna koncentracija ovih mikroorganizama. Naglašeno je da su denitrificirajući heterotrofi i nitrificirajući mokroorganizmi partneri u uklanjanju dušika jer nitrificirajući proizvode nitrate iz amonija, a heterotrofi denitrificiraju nastale nitrate do plinovitog dušika. Polaznicima je objašnjeno da navedene dvije grupe ne mogu provoditi svoje reakcije u istom prostoru i vremenu jer jednima za provedbu reakcija treba kisik, a druge moraju biti bez njega. Objašnjeno im je kako su u UPOV-ima zbog toga bazeni podijeljeni u aerirani i neaerirani između kojih mulj recirkulira da bi se procesi uklanjanja dušika uspješno odvijali.

Na kraju ovog dijela edukacije, polaznici su se upoznali s važnom grupom fosfor akumulirajućih organizama koji su odgovorni na napredno biološko uklanjanje fosfora. Biološko uklanjanje fosfora je moguće provesti i kroz rast običnih heterotrofnih mikroorganizama koje za rast trebaju fosfor, ali je u većini slučajeva potreba za fosforom ovih mikroorganizama manja od zahtjeva za uklanjanje fosfora. Zbog toga se u UPOV-u želi postići uspostava većeg udjela grupe fosfor akumulirajućih organizama koji u svom rastu mogu vezati mnogo veće količine fosfora od običnih heterotrofa. Polaznicima je objašnjen osnovni metabolizam fosfor akumulirajućih organizama kojima se uvođenjem anaerobne faze na početku procesa pročišćavanja omogućuje da asimiliraju određene organske tvari (npr. acetat) iz otpadne vode koje obični heterotrofi ne mogu asimilirati u anaerobnim uvjetima. Na taj način se fosfor akumulirajućim organizmima omogućava prednost nad običnim heterotrofima koji inače u aerobnim uvjetima rastu brže i nadvladaju fosfor akumulirajuće organizme. Objašnjeno je da fosfor akumulirajući organizami u anaerobnim uvjetima otpuštaju fosfor i asimiliraju organske tvari, a aerobnom bazenu koji slijedi nakon anaerobnog, uz pomoć asimiliranih organskih tvari iz anaerobne faze unose velike količine fosfora u svoju stanicu i tamo ih pohranjuju. Na taj način se poboljšava biološko uklanjanje fosfora u UPOV-u.

2.2. Provedba testova aktivnosti mikroorganizama

Usporedno s upoznavanja sudionika s različitim grupama mikroorganizama u obradi otpadnih voda, pokazana im je provedba testova aktivnosti navedenih grupa. Testovi aktivnosti mikroorganizama provedeni su na laboratorijskom reaktoru. Reaktor volumena 2 L u kojem su se provodili testovi imao je duplu stijenku kroz koji je konstantno cirkulirala vodovodna voda s ciljem održavanja temperature od oko 15 °C koja je odgovarala temperaturi u UPOV-ima u periodu provedbe testova. U reaktor su za potrebe praćenja i regulacije uvjeta testova ugrađene elektrode za mjerenje koncentracije otopljenog kisika, pH vrijednosti, senzor za mjerenje temperature i električna miješalica s regulacijom intenziteta miješanja suspenzije aktivnog mulja. Kontrolno-upravljačka jedinica služila je za praćenje i regulaciju zadanih parametara radi stalnog uvida o stanju u reaktoru. Također, laboratorijski je reaktor imao ugrađene dvije peristaltičke pumpe kojima se regulirala pH-vrijednost. Na slici 3 je prikazan sustav korišten u edukaciji.

Slika 3. Laboratorijski reaktor korišten u edukaciji

Sudionicima edukacije pokazana je provedba testovi nitrifikacije, denitrifikacije, anaerobnog otpuštanja fosfora i aerobnog vezanja fosfora kojima je izmjerena aktivnost nitrificirajućih mikroorganizama, aktivnost heterotrofnih mikroorganizama u provođenju heterotrofne anoksične razgradnje acetata u prisutnosti nitrata, aktivnost fosfor akumulirajućih mikroorganizama pri otpuštanju fosfora u anaerobnim uvjetima uz asimilaciju acetata te aktivnost fosfor akumulirajućih mikroorganizama pri asimilaciji fosfora u aerobnim uvjetima.

U testu nitrifikacije se mjerila brzina nitrifikacije od amonija do nitrata. Za provedbu testa, aktivni mulj je održavan u aerobnim uvjetima putem propuhivanja zrakom i miješanja, a u njega je za potrebe provođenja testa dodana određena količina amonijevih iona. Kroz sat vremena su mjerene koncentracije amonija i nitrata.

Testom denitrifikacije mjerila se aktivnost heterotrofnih mikroorganizama pri razgradnji izvora ugljika u obliku acetata u uvjetima bez kisika, ali s prisutnim nitratima pri čemu denitrificirajući mikroorganizmi umjesto kisika u TCA ciklusu koriste nitrate reducirajući ih do plinovitog dušika. Test je provođen s aktivnim muljem koji je bio u reaktoru nakon testa nitrifikacije.

Cilj testa anaerobnog otpuštanja fosfata je izmjeriti brzinu otpuštanja fosfata iz stanica fosfor akumulirajućih bakterija koje u anaerobnim uvjetima razgrađuju i ispuštaju polifosfat prethodno pohranjen u stanicu u aerobnim uvjetima ako u anaerobnim uvjetima imaju dostupne lakohlapive masne kiseline (acetat, propionat i butirat).

U testu aerobne asimilacije fosfata mjerila se brzina asimilacije fosfata u stanice fosfor akumulirajućih mikroorganizama nakon što su u anaerobnim uvjetima asimilirali acetat u obliku polihidroksi alkanoata. Za provođenje ovog pokusa korišten je mulj u reaktoru nakon pokusa anaerobnog otpuštanja fosfata.

2.3. Kemijske analize vode i aktivnog mulja

Pri provedbi testova aktivnosti opisanih u prošlom poglavlju, sudionicima edukacije pokazani su postupci pri uzimanju uzoraka aktivnog mulja i kemijskih analiza potrebnih za dobivanje rezultata u testovima aktivnosti. Određivanje koncentracije aktivnog mulja prikazano je na slici 4. Koncentracija je određena kao ukupna suspendirana tvar dobivena sušenjem uzorka aktivnog mulja na filtru kroz koji je profiltriran nakon čega je filtar s muljem spaljen da se dobije anorganski dio zaostao na filtru. Iz razlike mase mulja na filtru prije i poslije spaljivanja dobivena je koncentracija organskog dijela aktivnog mulja koja je služila kao vrijednost koja ukazuje na koncentraciju bakterija u mulju. Rezultati

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testova aktivnosti se daju kao specifična brzina određene biološke reakcije tako da se brzina reakcije podijeli sa koncentracijom organske tvari u mulju i vremenom provedbe reakcije.

Sudionicima je pokazana provedba kemijskih analiza koje su potrebne da se odrede aktivnosti aktivnog mulja u testovima koji su provedeni u sklopu edukacije. Kemijske analize s koje su im pokazane bile su:

- Amonij (ISO 7150-1)
- Nitrat (ISO 7890-1-2-1986)
- KPK (ISO 6060-1989)
- Orto-fosfat (DIN EN ISO 6878)

Provođenje analiza u laboratoriju prikazano je na slici 5.

Slika 4. Određivanje koncentracije aktivnog mulja tijekom provedbe testova aktivnosti mikroorganizama

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Slika 5. Provođenje kemijskih analiza u laboratoriju na lokaciji UPOV-a Poreč Jug

2.4. Mikroskopiranje aktivnog mulja

U sklopu edukacije sudionicima je ukazano na važnost praćenja kvalitete aktivnog mulja kroz različite analize koje uključuju pregled mulja putem mikroskopa. U UPOV-ima koji imaju uključeno taloženje mulja u svoju tehnološku shemu važno je da bakterije rastu u flokulama što olakšava taloženje i odvajanje obrađene vode. Prisutnost i brojnost nitastih bakterija su kod takvih UPOV-a važna karakteristika jer mogu uzrokovati sporo taloženje mulja. Mikroskopski pregled aktivnog mulja i mjerenja taloživosti mulja mogu dati informaciju o stanju mulja. Polaznici su dobili osnovne informacije o mikroskopiranju i interpretaciji rezultata opažanja. Mikroskopiran je aktivni mulj UPOV-a Poreč Jug.

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – **STUDIJA POREČ**

IZVJEŠĆE 17 – dio 4/4

EDUKACIJA DJELATNIKA: MODELIRANJE UPOV

Ožujak 2022

Zajednica izvršitelja

Naručitelj

Krajnji korisnik

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IZVJEŠĆE 17 – dio 4/4

EDUKACIJA DJELATNIKA: MODELIRANJE UPOV

15 ožujak 2022

mr.sc. Božidar Deduš, dipl. ing.
Ovlaštenik Zajednice izvršitelja
Proning DHI d.o.o.

14 ožujak 2022

prof.dr.sc. Damir Brdjanovic, dipl.ing.
Voditelj stručnog tima
IHE Delft

Evaluation and efficiency monitoring of the new implemented sewage network and wastewater treatment construction in the larger city of Poreč.

Report 9 – Training BioWin Modelling

Odvodnja Porec

2022 03 14

Definitive Concept

innovative wastewater solutions

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Responsibility

Project Title	:	Evaluation and efficiency monitoring of the new implemented sewage network and wastewater treatment construction in the larger city of Poreč.
Working Title	:	Report 9 – Training BioWin Modelling Odvodnja Poreč
Project Description:	:	Study of the environmental impact as the result of upgrading and operation of the wastewater system of the larger city of Poreč on coastal sea water quality. Integrated evaluation of the sewer system, wastewater treatment systems, coastal discharge, and sea water quality based on modelling tools.
Document number	:	ASM-20220314-RAP117
Status	:	Definitive Concept
Date	:	2022 03 14
Responsible Author(s)	:	Sebastiaan. C.F. Meijer Ph.D. MSc., ASM Design B.V.
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Content

1 Introduction

1.1 General project introduction

The infrastructural investment “Sewerage and Wastewater Treatment Plants of City of Poreč”– Project Poreč, co-funded by European Union, is one of the largest investments in the public sector in Republic of Croatia. It involves rehabilitation and extension of the existing sewerage system and construction of four new wastewater treatment plants (WWTPs). The goal is to better protect the environment in and around the Poreč coastal area. Complementary a project is developed titled “Integrated Modelling of Wastewater Infrastructure System of City of Poreč” – Modelling Project. This project is an integrated environmental assessment to obtain a better understanding of the environmental impact of the system performance which is evaluated under range of operational conditions. A scenario study is developed using state-of-the-art (modelling) tools and methods which allows a holistic assessment of the wastewater system. The results of this study are in assistance of future operations and wastewater management in the region and used to elevate knowledge and professional skills of local water sector professionals.

The Modelling Project consists of 4 main components, namely:

- Part 1: Modelling the sewage collecting and transport system of City of Poreč,
- Part 2: Modelling of operation and performance of 4 WWTPs of City of Poreč,
- Part 3: Model assessment impact offshore outlets on aquatic water quality,
- Part 4: Establishment of the experimental laboratory setup for monitoring and optimization of wastewater management and operation.

Including a training is organized to extend the capacity of water professionals in the use of wastewater modelling for future assessments.

The Modelling project has a holistic system approach covering collection, processing, and aquatic discharge of wastewater, the interrelation between the different wastewater systems and impact on the environment, public health, and coastal seawater quality.

Several scenarios are calculated to explore the impact of Project Poreč on the previous mentioned factors and to and establish the best methods for management of the wastewater systems from an integrated perspective.

Modelling is used to demonstrate how upgrade of the Poreč wastewater system improves the environment. Further insight is developed in the overall interaction of the sub-systems on seawater quality. Knowledge is developed on how to operate and optimize the different wastewater systems, with the best overall results.

1.2 Project goals

The overall objective of the Poreč modelling project is to demonstrate how upgrading the total wastewater system improves the sea water quality in the Poreč costal region. Therefore, the total wastewater system is modelled consisting of several sub-systems. By modelling the WWTP under different (extreme) conditions it is investigated how effluent discharge load and quality will affect the sea water quality. For each studied scenario, effluent concentration and flow profiles are calculated. These data are subsequently used as input for sea water quality modelling from which the environmental impact is calculated.

1.3 Context of this report

This report belongs to the reports in the series “modelling project part 2: Modelling of operation and performance of 4 WWTPs of City of Poreč”. Each WWTP is modelled and reported in a series of 4 documents of which this is the final. For accessibility the reports are set up using identical format and methods. Modelling project Part 2 is developed in four steps:

- Step 1: Static WWTP modeling using detailed design data. In the total project this is report number 5 consisting of 4 sub-reports, one for each WWTP (report number 5.1 to 5.4).
- Step 2: Dynamic WWTP modeling based on dynamic winter and summer influent measurements (data 2019). In the total project this is report number 6, consisting of 4 sub-reports, one for each WWTP (report number 6.1 to 6.4).
- Step 3: Analysis of operational WWTP scenarios up to the year 2045. In this step a series of operational scenarios are developed, and the potential coastal discharge loads and concentrations are quantified based on extrapolation simulations. In the total project this is report number 7, consisting of 4 sub-reports, one for each WWTP (report number 7.1 to 7.4).
- Step 4: Model calibration and validation based on new operational measurements done in 2022. The model validity is tested by reproducing a new influent and effluent data set without the need of significant model adjustments. In the total project this is report number 8, consisting of 4 sub-reports one for each WWTP (report number 8.1 to 8.4).
- Step 5 (this report): On location in person training of the technological team of Odvodnja Poreč in the use of BioWin software and application of the developed WWTP models for plant assessment (report number 9).

1.4 Background and previous investigations

This research is part of an integrated environmental assessment of the wastewater transport, collecting and treatment system including the coastal recipient. The goal of this research is to obtain a better understanding of the environmental impact of modernization of the City of Poreč wastewater system and its performance. This report is part of a series studying the operation of 4 wastewater treatment plants of the larger City of Poreč. Models of the wastewater treatment are developed from detailed design information and influent flow and concentration data are measured in the summer and winter of 2019 and winter of

2022. In previous reports (numbered report 5, 6 and 7) model evaluations have been performed simulating a range of operational conditions and future scenarios. In report number 5 the average performance is evaluated using a static model. In report number 6 models are further developed to test and evaluate operation under realistic dynamic conditions. In report number 7 models are projected towards winter and summer conditions in 2045 including a dynamic scenario with peak loading and rain event. Based on the simulations results, the impact of the upgraded wastewater facilities on the costal seawater quality is assessed. In report 8 the validity of the previously developed models is further investigated by calibrating the model using a new dataset measured in 2022, including operational performance data. It is tested if the previously developed dynamic model can reproduce measured effluent quality without having to alter critical model parameters. The study adds to the overall validity of the previously performed model calculations and scenario projections.

2 Training program

2.1 Training location and participants

Training is organized starting Monday, March 7th to March 9th 2022. Training is organized at the location of the head office of Odvodnja Poreč. Address: Odvodnja Poreč d.o.o., Mlinska 1, 52440 Poreč, Fax: 075 805 698, www.odvodnjaporec.hr. Trainer is Mr. Sebastiaan C. F. Meijer PhD. MSc., Managing director ASM Design B.V (meijer@asmdesign.nl). Participants of the training (in random order): Karlo Gospić (karlo.gospic@odvodnjaporec.hr), Zoran Ardalič (zoran.ardalic@odvodnjaporec.hr), Ugo Puniš (ugo.punis@odvodnjaporec.hr), Mateo Stifanic (mateo.stifanic@odvodnjaporec.hr).

Figure 1. At Odvodnja Poreč head office training location and field trip WWTP Poreč-North.

2.2 Learning goals

The learning goals are to get a quick general introduction in the use of modelling and modelling software with a strong emphasis on practical application of the BioWin models developed in this project. For the training WWTP Poreč-North is selected as case study. Under supervision of the trainer, participants have developed a complete (dynamic and static) model of WWTP Poreč-North including sludge dewatering, influent specification, process control design, and operational assessment (data presentation and evaluation).

2.3 Training materials and methodology

A full documentation of the methodology and modelling approach is found in reports 5 to 8. Additional teaching materials are introduced for the purpose of this training and included in this report (appendix), as well as several data files (belonging to project deliverables).

2.4 Program

The final program was decided in cooperation with the participants. The session started with handing over and installing BioWin software and licenses (BioWin and BioWin Controller) on the network of Odvodnja Poreč.

- Day one, was dedicated to theory was discussed on the do's and don'ts of general model application and a short theoretical introduction. The main topic was how to set up a WWTP model using BioWin and getting acquainted with the BioWin software, preparation of input data and influent specification.
- Day 2 as a case study, WWTP Poreč-North was modelled. Starting with setting up a simplified (static) model in BioWin, learning the functionality of the software as while developing the model step by step. The day finished with a static model calibration according to the approximate operation of WWTP Poreč-North.
- Day 3 the model is further developed including waste sludge storage and dewatering using dynamic influent input and process controls. The model is used for a dynamic operational assessment. Different types of process control are tested. The training was finalized by a visit to WWTP Poreč-North. Here we interviewed the operator to establish some of our model findings in practice.

2.5 Training summary

- Software installation and use of the hardware dongle (appendix 1).
- General introduction on modelling (presentation in appendix 3)
- Getting started with BioWin; General functionality (BioWin manual in appendix 2)
- Tips and tricks for setting up a model in BioWin (appendix 3).
- Building a simplified model; Case study WWTP Poreč-North (appendix 4)
- Influent specification (appendix 2)
- Model calibration (appendix 2)
- Dynamic inputs and process control
- Operational assessment

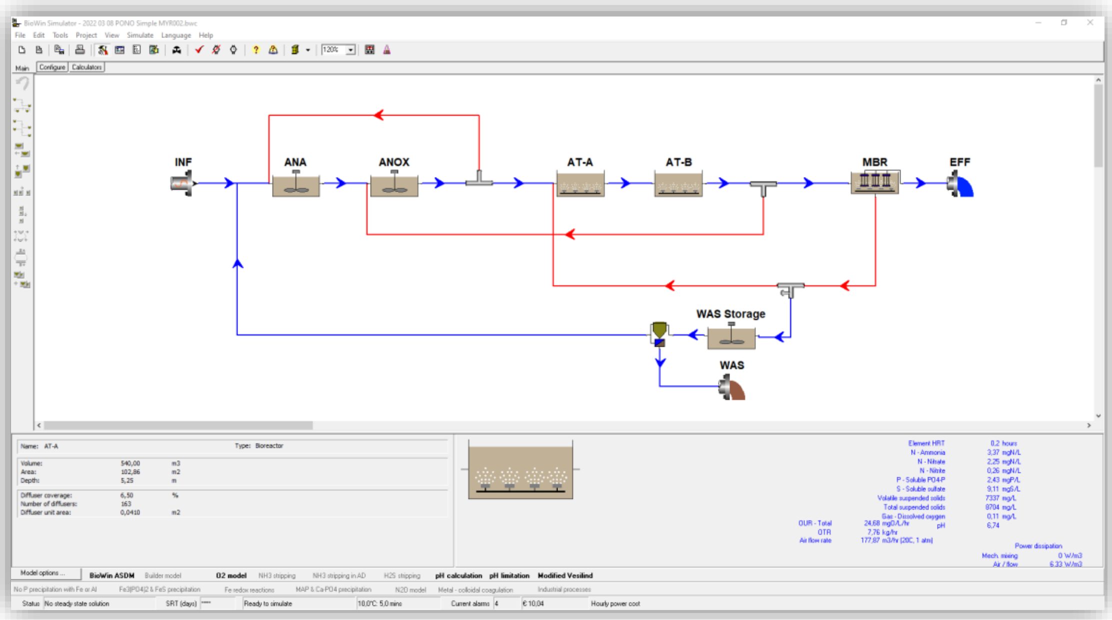


Figure 2. Simplified BioWin model of WWTP Poreč-North developed during the training.

2.6 Deliverables

- BioWin and BioWin Controller license (one year lease) including hard lock software protection key. License owner registered by Envirosim Ltd. in name of Hrvatske Vode, mr. Karlo Gospić, mag. ing. aedif, Odvodnja Poreč, HR-52440 Poreč, Mlinska 1, phone number +385915493422. Software is delivered and installed in working order and applied for the training session.
- Developed BioWin models of four WWTP's under different scenarios belonging to reports series 5 to 8, including influent specification files and dynamic controller files.
- Influent assessment calculations belonging to reports series 5 to 8.
- Data is shared and available for download for 2 weeks via: Odvodnja Poreč Shared - Google Drive

2.7 References

- Installation hardware and hard lock: https://envirosim.com/support#faq
- BioWin references, articles and (video) tutorials: https://envirosim.com/support#ref
- Sebastiaan C.F. Meijer and Damir Brdjanovic, 2012, A Practical Guide to Activated Sludge Modeling, ISBN: 9789073445260

2.8 Conclusions model results and operation

Operational parameters and the methods of control are comparable to what is assumed in the model, however, can further be improved regarding operation and control of recycle rates, aeration control and flow division over the 3 parallel reactors. It was discussed with the plant operator how current operation continuously is changed to find optimal operational conditions.

A possible problem identified based on modelling, concerned P-release in the waste sludge storage tank. This results in recycling of phosphate via the dewatering and centrate and overall decreased performance of phosphorus removal. In an interview with the operator this problem was recognized. The practical measure applied is not to store waste activated sludge storage longer than 3 hours, especially during summer conditions.

A bottleneck for sludge waste is sludge disposal logistics because trucks do not transport sludge over the weekend. In the model, 10 hours a day operation is taken in account however, not 5 days a week of sludge transportation. This affects the sludge concentration in the AT that cannot become too high. This could be investigated by improving the model on this detail.

During the day (under winter conditions) high peak loads of ammonium are measured in the aerobic tank (up to 10 mgNH4-N/L). Similar peaks are reproduced by the model. This indicates that the ammonium removal capacity is limited at peak loading (starting at approximately 11:00-13:00 hours) and by cold temperature. Evaluated over the whole year, nitrification capacity is however sufficient according to the model calculations (Total N < 15 mg/L). This is also predicted for the design in the year 2045.

The effluent buffer helps to bring down the effluent peaks which benefits the water quality in the recipient.

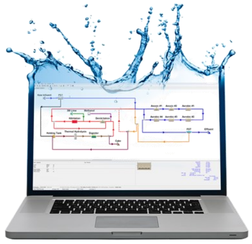
A possible point op optimalization is to increase the recycle flows during low influent loading, to reduce effluent ammonium peaks and improve denitrification during low (nightly) loading conditions.

Some ammonium release in the WAS tank is modeled however, calculated less than 3% of the total influent load and therefore (based on modelling) most likely not a problem.

The general conclusion is that this training shows that a simplified model with a minimum of calibration is very useful for static performance (average) as well as dynamic performance evaluation. Detailed insights can be obtained from the simulation environment that are confirmed from practical experience.

This training example shows the usefulness of model application and confirms how investing in modelling technology can benefit the organization.

Appendix 1. BioWin and BioWin Controller product pages



BIOWIN

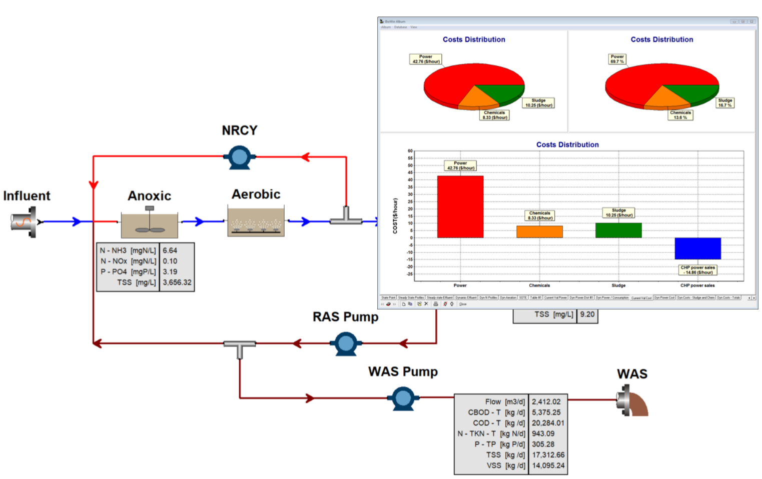
Why BioWin?

BioWin wastewater process simulation software ties together biological, chemical, and physical process models to provide insight into the whole plant. BioWin simulations help engineers and operators make decisions that reduce capital and operating costs and ensure treatment objectives are met. BioWin has been a recognized leader in the simulation field for over 25 years.

Who Uses BioWin?

BioWin is used around the world by:

- Consulting engineers
- Infrastructure owners (e.g. cities, regional municipalities, water authorities)
- Equipment manufacturers / suppliers
- Wastewater treatment plant operations companies
- Academic institutions



What is BioWin Used For?

BioWin is used to:

- Select optimal treatment processes with minimal capital investment
- Explore strategies for reducing energy consumption and operating costs
- Evaluate expansion options for existing treatment plants
- Make daily decisions about plant operation
- Teach students and operators fundamental wastewater treatment concepts
- Build model extensions and conduct research into emerging technologies

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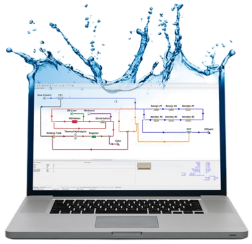
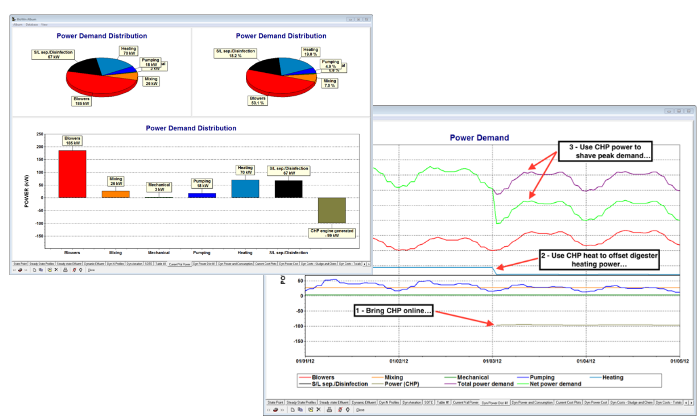


BIOWIN

BioWin Key Features

- Integrated activated sludge / anaerobic digestion model enables whole-plant modeling from influent to effluent
- Most accurate and intensively researched biological nutrient removal model reduces required calibration effort
- State of the art chemical phosphorus removal model allowing for simultaneous use of ferrous, ferric, and aluminum metal salts on a single flowsheet
- Chemically enhanced primary treatment modeling
- Sulfur modeling including sulfate oxidizing/reducing bacteria, hydrogen sulfide stripping, and iron sulfide precipitation
- Industrial compound modeling with inhibition kinetics and potential simultaneous biodegradation and stripping removal mechanisms
- Modeling of multiple phosphorus recovery precipitates including struvite, brushite, and vivianite
- Cellulose tracking and recovery
- Modeling of anaerobic ammonia oxidizing bacteria for investigation of side- and main-stream deammonification strategies
- Calculation of blower power requirements accounting for factors such as inlet air temperature and relative humidity and pressure losses in the air delivery system
- Ability to explore onsite power generation and heat recovery via CHP
- Comprehensive OPEX calculations including varying daily/seasonal electricity tariff rates
- User-friendly flowsheet drawing tools (undo feature, element copy/paste, element alignment)
- Automatic report generation in both Word and Excel formats



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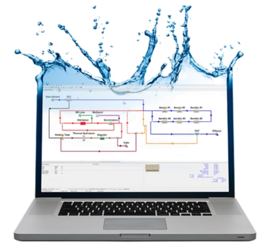
BW
CONTROLLER

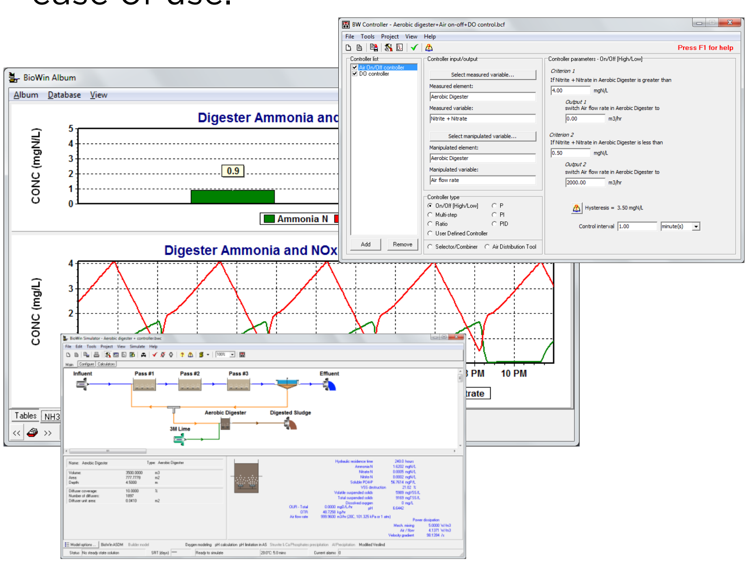


Whole Plant - Control System Simulation

BW Controller is designed to work in conjunction with BioWin, and can be used to address the most complex process control issues.

It helps engineers to evaluate recent improvements in online measurement and control technology effectively and explore and develop more sophisticated, innovative, and feasible control systems for sustainable wastewater treatment.

BW Controller provides an extra level of sophistication for your BioWin simulations without compromising on ease of use.



Empower the dynamic whole plant capabilities of BioWin

Simulate advanced process control strategies beyond BioWin's built-in control facilities :

- Controlling air flow rates in reactors based on DO and/or ammonia concentrations at various locations using feed-forward and feed-back strategies
- Control of internal recycle flow rate based on nitrate concentration
- Control mixed liquor suspended solids concentrations by adjusting wastage flow rate
- Use pH measurements to adjust air flow to control nitrification, denitrification and anammox sidestream N removal systems
- Change chemical dosing rates based on influent and effluent flows, concentrations, or mass rates.
- Adjusting on/off aeration periods to control alkalinity/pH levels

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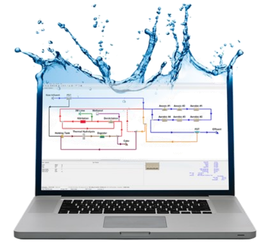
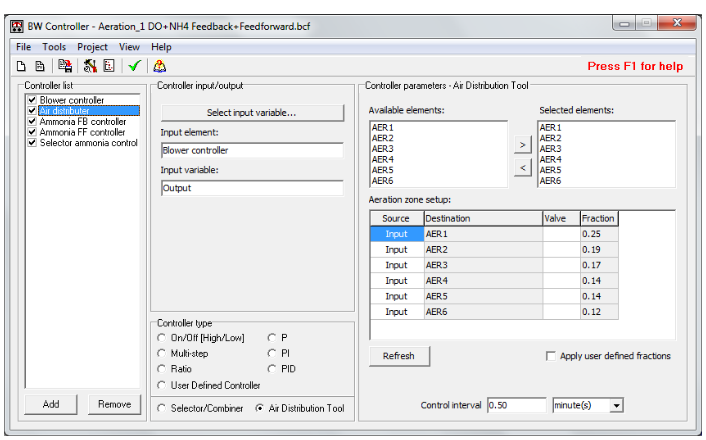
BW CONTROLLER



Control Types

- 2-step control (On/Off or High/Low) - to maintain a measured variable between upper and lower setpoints
- Multi-step control - increase or decrease a manipulated variable stepwise
- Ratio control - manipulated variable and measured variable are held at a constant ratio to each other
- Proportional (P) control, Proportional-Integral (PI) control, Proportional-Integral-Derivative (PID) control
- Selector - choose between the output of two controllers
- User-defined controller - write your own control law for advanced control.
- Air flow distribution control - model the air distribution to different reactors



Created by process engineers... for process engineers.

Flexibility in Operations

- Multiple controllers - use as many controllers as you require
- Cascade control - use the output of one controller as an input to another controller
- Any BioWin output variable or any user-defined variable can be assigned as the measured variable
- A wide range of manipulated variables including: Flow (wastage, recycle etc.), air/power supply rates, chemical feed, fractionation and composition of influent streams
- Integrates seamlessly into BioWin

Approach

BW Controller runs as a separate Windows application and links to BioWin. This means you can choose to add this analysis to any configuration or continue to use BioWin (with its variety of embedded controls) without being forced to worry about control issues.

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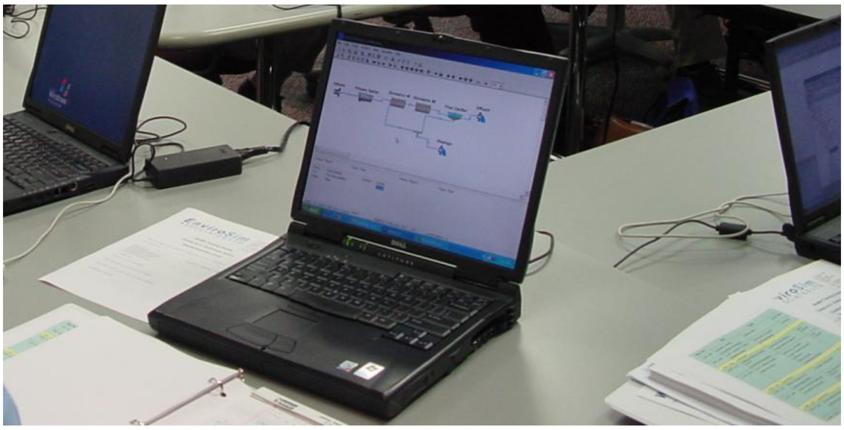
Appendix 2. BioWin Quick Feature Tour

BioWin Training Course



Introductory Topics

EnviroSim Europe

Notice

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Course Objectives

BioWin courses are modular and are designed as a training exercise for engineering personnel in the application of BioWin. If the majority of attendees are "new" BioWin users, the primary objective is to provide training on the BioWin software package itself. This will be achieved through the medium of a number of case studies focusing on process applications as well as design and operating issues. The case studies and PowerPoint presentations included in the folder cover a wide range of topics listed above in the table of contents. A course can also be assembled for the modules to look more in depth into process engineering issues and the modelling approach used in solving them.

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BioWin familiarization

1 INTRODUCTION

This familiarization case demonstrates a number of the features in BioWin. Aspects covered in this case include the basic BioWin interface, loading a BioWin configuration file, specifying data for configuration elements, and running steady state and dynamic simulations.

2 THE INTERFACE AND LOADING A FILE

Start BioWin and view the main simulator window. All simulation tasks are executed from here. The interface consists of menus, toolbars, the drawing board, summary panes and a status bar. For a detailed description, view the "*Main Simulator Window*" chapter. In this case you will only get a brief overview.

1. From the **File** menu, click on **Open** and load the **An Example** configuration file from the **DATA** directory. The screen view will be similar to that shown below.

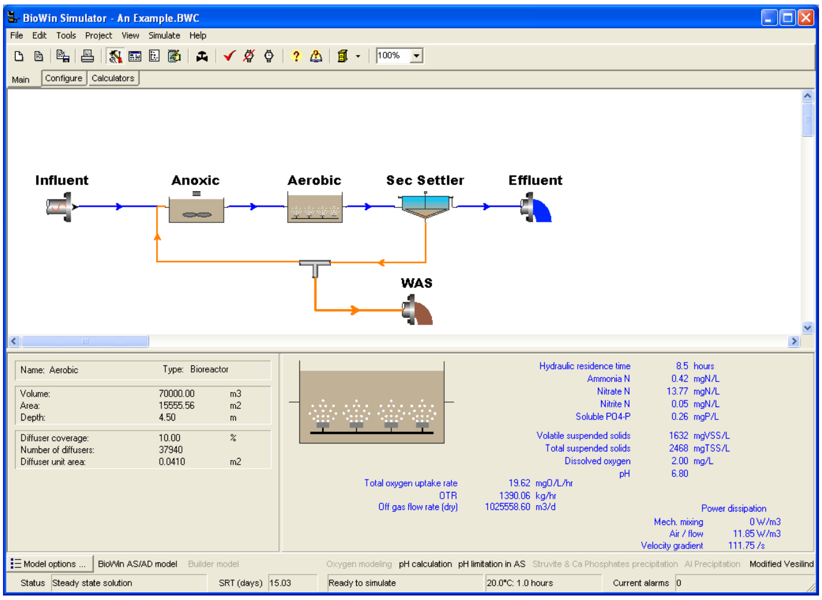

FIGURE 3.1. *THE EXAMPLE CONFIGURATION.*

2. Move the cursor over the toolbar. A fly-by hint appears when you pause over a button. The **Select/Drag/Edit** tool at the left of the lower tool bar should be depressed (i.e. on) at this stage.

Element Selection Tool

3. A status bar at the bottom of the window displays various pieces of information.

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4. Move the arrow cursor across the drawing board. The cursor changes to a hand as you cross over elements on the drawing board. When you pause over an element, information on that element appears in the two panes below the drawing board – physical data in the left pane and performance data in the right pane. This function allows you to get a summary overview of system information.

Selection Cursor

5. Move the cursor over an element and click the right mouse button. A local menu appears. [Don't select any options yet!]. This will allow you to access various options for that element (see below).

Hint: As a general rule when using BioWin, clicking the right mouse button often helps!

3 PHYSICAL AND OPERATIONAL DATA

1. Move the cursor over the **Aerobic** element (a completely mixed aerated bioreactor) and double click – or click the right mouse button on the element and select the **Properties** command. A tabbed editing dialog box opens (see below). This contains all the physical and operational data for the element. View the information on the **Dimensions** and **Operation** tabs. [Don't change any information yet. We'll accept the sizing of this aerated zone with DO controlled at a setpoint of 2 mg/L].

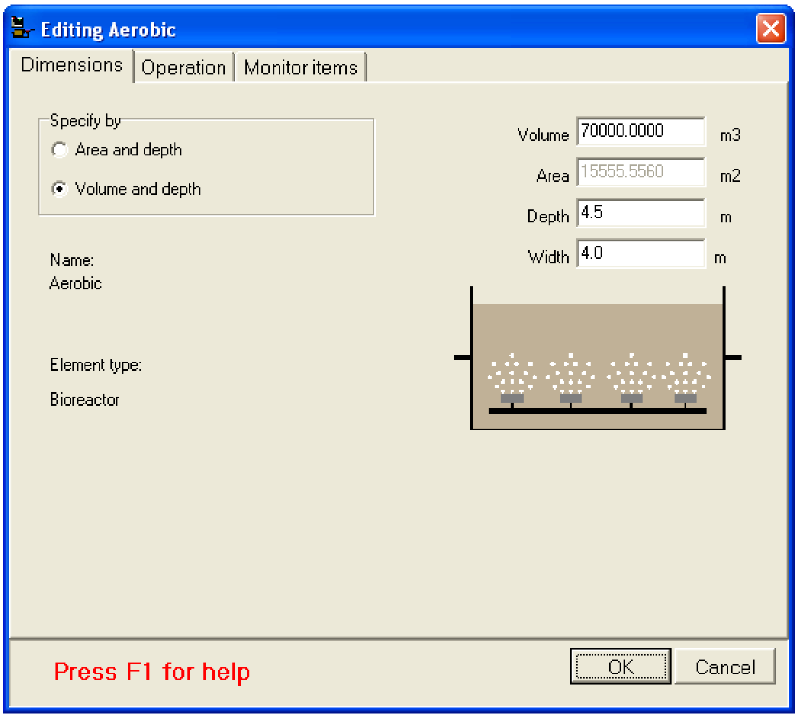

FIGURE 3.2. *THE BIOREACTOR DIMENSIONS TAB.*

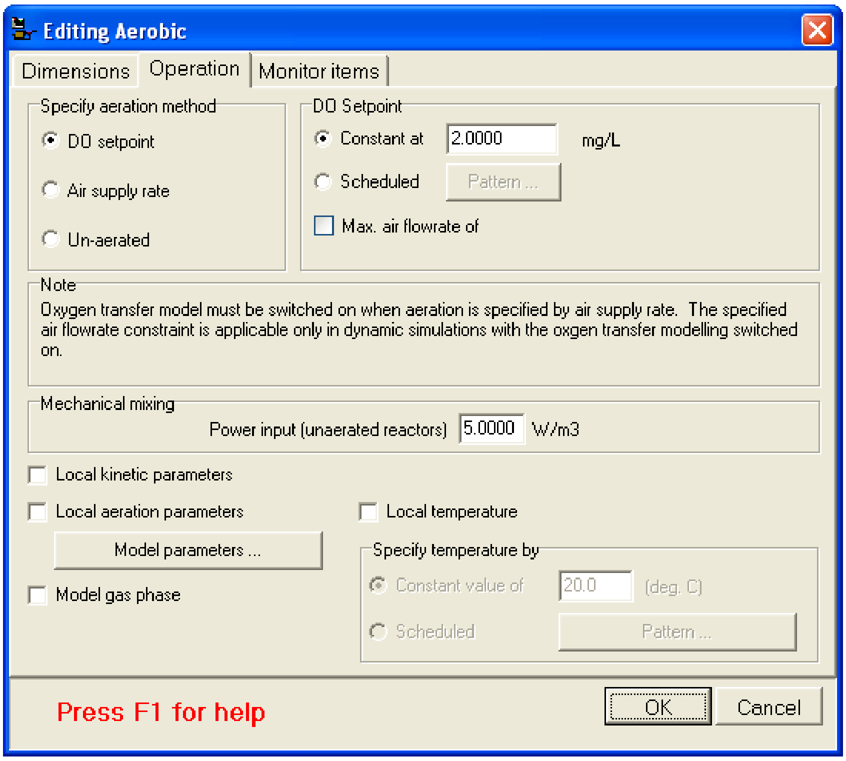

FIGURE 3.3. *THE BIOREACTOR OPERATION TAB.*

2. Now try double-clicking on other elements and view the details for this configuration.
3. Click on an element and keep the left mouse button depressed. You can drag and drop the element in a new position, and re-arrange the configuration to your liking.

Hint: Try right-clicking on the arrow head of a pipe, and view the **Properties**. There are a number of options for re-arranging the pipe layout.

---

4 CHECKING INFLUENT DATA

1. Double click on the **Influent** element, and click on the **Edit data** button. At this stage we won't change any data.

Hint: When viewing influent data, point the cursor at a column heading and click the right mouse button. There are many options for entering and manipulating data.

---

2. **Close** the dialog.

Hint: The pane at the lower right displays the flow-weighted average influent concentrations.

---

5 VIEWING INFORMATION AND SIMULATION RESULTS

The panes below the drawing board provide a limited overview of system information. Comprehensive information can be viewed in two ways – via the **Explorer** or in the **Album**.

1. Select **Explorer** from the **View** menu – or click on the **Explorer** toolbar button – or press **Ctrl + E**. This opens the **Explorer** - a tree-like view of system information.

The Explorer button

2. Experiment with expanding different levels. **Hint**: Try double clicking on an element name or the parameters item in the right panel.

3. Select **Album** from the **View** menu – or click on the **Album** toolbar button – or press **Ctrl + A**. This opens the **Album**. This contains user-customized information in the form of custom tables, pre-formatted element information, and charts. The **Album** can contain many pages of information.

The Album button

4. Click on the page name tabs along the bottom and view the different examples. **Hint**: Try clicking the right mouse button on different parts of the **Album** pages (including the name tabs at the bottom).

5. Select **Add page** from the Album menu, and choose one of the layout options. After adding a page, click the right mouse button on a blank panel and experiment! Expect to encounter difficulties at this stage – subsequent cases will provide detailed instructions.

6 RUNNING A STEADY STATE SIMULATION

Steady state simulations provide a solution for the system based on the flow-weighted average influent loading to the system (and the time-weighted average for any timed operational changes such as a schedule of DO setpoints in an aerated reactor).

1. Select the **Steady state** command in the **Simulate** menu – or click on the **Steady State** button on the toolbar. This opens the simulator player dialog. **Hint**: If you re-position the simulator player dialog at a convenient spot on the screen that's where it'll appear next time.

Steady state button

2. Click on the play button. A dialog box appears when BioWin has found the solution.

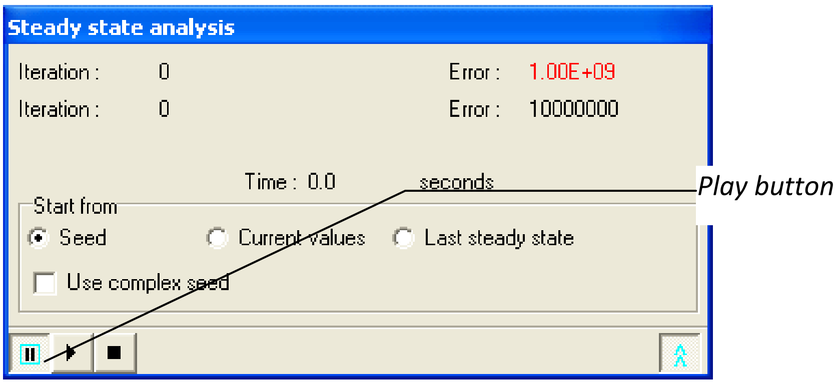

FIGURE 3.4. *THE STEADY STATE SOLVER DIALOG BOX.*

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Note: Most steady state solutions are found in ten or so iterations. In unusual circumstances the solver may "stick" – that is, the error value does not decrease from iteration to iteration. In this situation click on the stop button. Often this indicates a difficulty with the influent data such as a nutrient deficiency (or an Alkalinity deficiency in an aerobic digester, perhaps). Alternatively, you may have a "difficult-to-solve" system. One trick is to try conservative solver settings. To do this, select the menu command **Project|Current Project Options**, click the **Numerical Parameters** tab, and click the **Options**… button in the **Steady State Solver** group. At the bottom of the resulting dialog box there is a large button that you can click to set conservative solver parameters (see **Steady State Solver Options** in the **Manage Projects** chapter).

7 RUNNING A DYNAMIC SIMULATION

Dynamic simulations show the time-varying system response based on the time-varying influent loading to the system (and subject to any time-varying operational changes such as a schedule of DO setpoints in an aerated reactor).

1. Select the **Dynamic simulation** command in the **Simulate** menu – or click on the Dynamic Simulation button on the toolbar. This opens the simulator player dialog.

Dynamic Simulation button

2. Click on the play button. This brings up a dialog box where you can set various options such as the duration of the simulation. Clicking on the **Start** button starts the dynamic simulation.

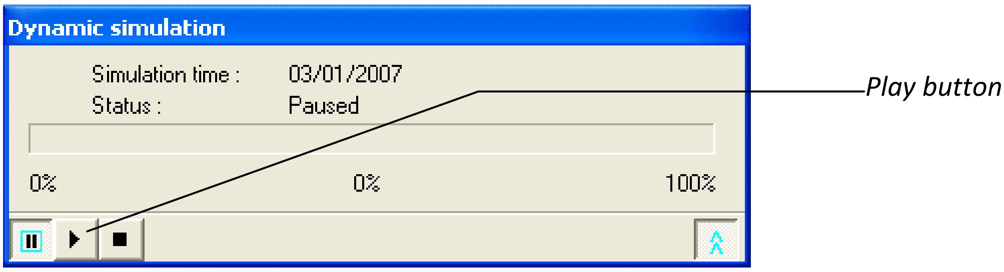


FIGURE 3.5. *THE DYNAMIC SIMULATOR CONTROL DIALOG BOX.*

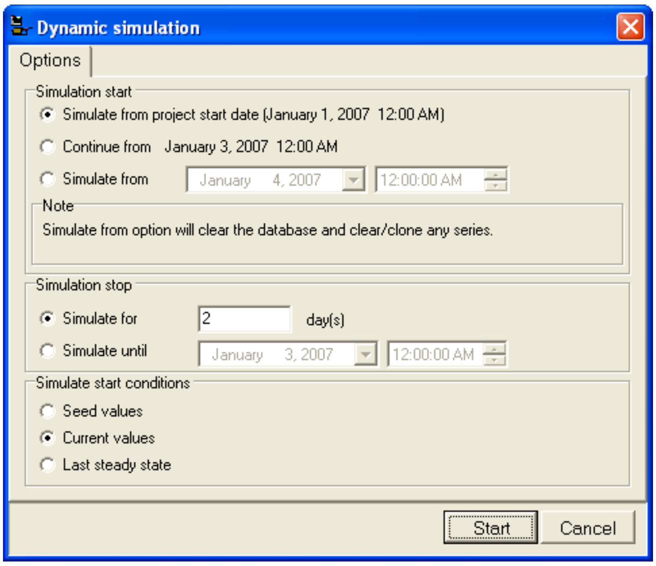


FIGURE 3.6. *THE DYNAMIC SIMULATION OPTIONS DIALOG BOX.*

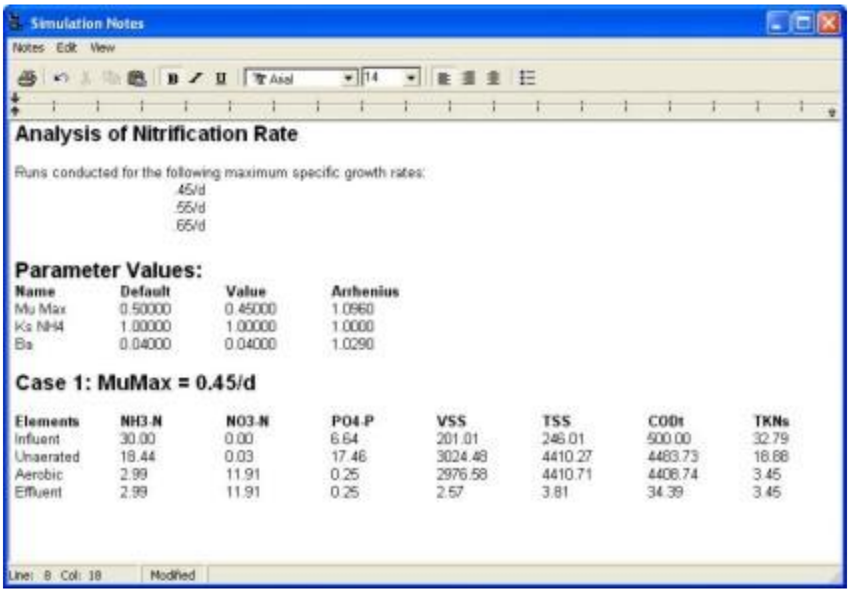
Note: Even if you are only interested in dynamic system response, it is useful to first calculate the steady state solution, and then start the dynamic simulation from these "Current" values.

Note: In the **Album** a time-series chart set up for 24 hours may appear blank or may not reflect a change you expected to see. Perhaps you need to change the scale on the bottom axis depending on what you specified as the starting date for the simulation.

8 KEEPING TRACK OF THINGS AND GENERATING REPORTS

Simulation Notes button

BioWin offers a number of features to aid in creating attractive, professional reports. You have your own internal Notes editor (shown below) to help keep track of project details. Access this scratch pad from the **Project|Notes** command or by clicking on the Notes button on the toolbar. It also is very easy to get results from BioWin into your word processor, spreadsheet or other applications. Charts, tables, the drawing board view of the system layout, etc. can be copied from BioWin and pasted to your report. Tables can be exported as tabbed text and then quickly converted to tables.


Simulation Notes
Notes Edit View

Analysis of Nitrification Rate

Runs conducted for the following maximum specific growth rates:
45/d
55/d
65/d

Parameter Values:

Name	Default	Value	Arrhenius
Mu Max	0.50000	0.45000	1.0960
Ks NH4	1.00000	1.00000	1.0000
Bs	0.04000	0.04000	1.0290

Case 1: MuMax = 0.45/d

Elements	NH3-N	NO3-N	PO4-P	VSS	TSS	CODt	TKNs
Influent	30.00	0.00	6.64	201.01	246.01	500.00	32.79
Unaerated	18.44	0.03	17.46	3024.48	4410.27	4483.73	18.88
Aerobic	2.99	11.91	0.25	2976.58	4410.71	4408.74	3.45
Effluent	2.99	11.91	0.25	2.57	3.81	34.39	3.45

Line: 8 Col: 18 Modified

FIGURE 3.7. BIOWIN'S INTERNAL NOTES EDITOR.

9 CUSTOMIZING BIOWIN

There are a number of parts and features of BioWin that can be customized to look how you want. When you customize BioWin, you essentially are changing the default settings of the BioWin work environment and all new projects that are created therein. This functionality is accessed via the **Project|New Project Options** menu command used to customize BioWin. A detailed description of the features accessed from this tabbed dialog is provided in the "*Customizing BioWin*" chapter.

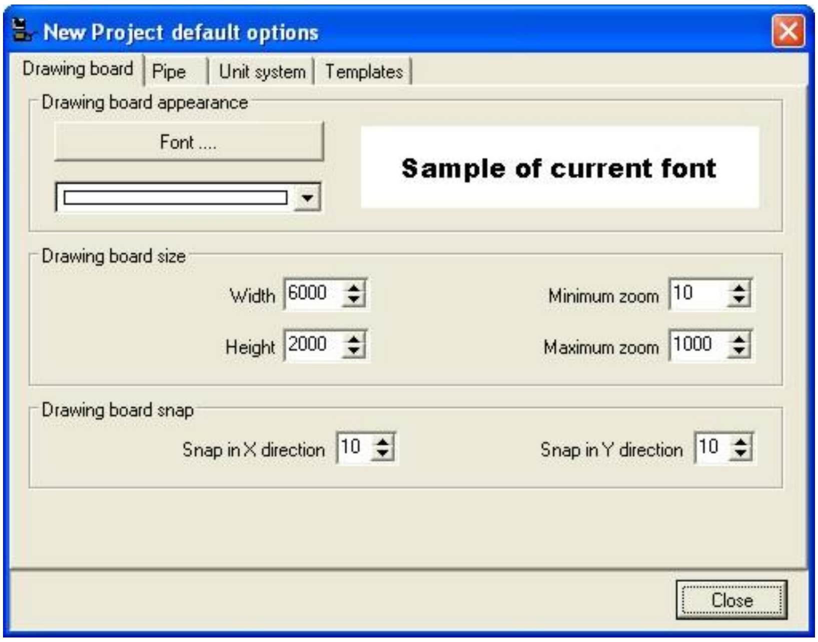


FIGURE 3.8. *MANY FACETS OF BIOWIN MAY BE CUSTOMIZED TO SUIT YOUR NEEDS.*

The **Tools|Customize** command defines your "default" setup for when you start a new project; for example, you may always want to start with SI (m^3/d, etc.) units. You can override these preferences for the current project through the **Project|Current Project Options** command. Since project options are file specific, they "travel" with that file. For example, if you define a set of project options for "Project A" on your copy of BioWin and then open the "Project A" file in someone else's copy of BioWin, you still will see your defined project options. As before, these project options will override any similar settings that the owner of the other copy of BioWin has set as defaults using the **Tools|Customize** command.

Building a Configuration

1. INTRODUCTION

This case demonstrates how to build a new configuration and add tables to the Album. Aspects covered in this case include building a BioWin configuration, moving and connecting elements on the drawing board, specifying data for elements, changing model parameter values, and setting up tables to record your simulation data.

2. THE CASE 2A SYSTEM

A large city has a nitrification/denitrification system – a Modified Ludzack Ettinger configuration. Phosphorus removal is achieved in a tertiary chemical precipitation system. The client experiences problems in the tertiary system. You want to investigate achieving P removal biologically in the existing tankage. The system has the following characteristics:

TABLE 1. *THE CASE 2A SYSTEM.*

Unaerated reactors:	Four (each 4000 m^3)	Depth = 4.5 m	Unaerated
Aerated reactors:	Two (each 28000 m^3)	Depth = 4.5 m	DO = 2 mg/L
Clarifier (Ideal):	Area = 12000 m^2	Depth = 4.5 m	
Influent:	Average Flow = 330000 m^3/d		
	COD = 246 mg/L	TKN = 24 mgN/L	
	TP = 5.4 mgP/L	ISS = 15 mg/L	
	Alkalinity = 6 mmol/L		
Wastewater fractions:	f_{BS} = 0.12	f_{UP} = 0.10	
	f_{US} = 0.07	f_{NA} = 0.75	
RAS recycle:	165000 m^3/d (50%)		
NML recycle:	990000 m^3/d (300%)		
Wastage rate:	3700 m^3/d (constant rate)		
Temperature:	18°C		
Nitrification rate (AOBs):	0.8 /d		

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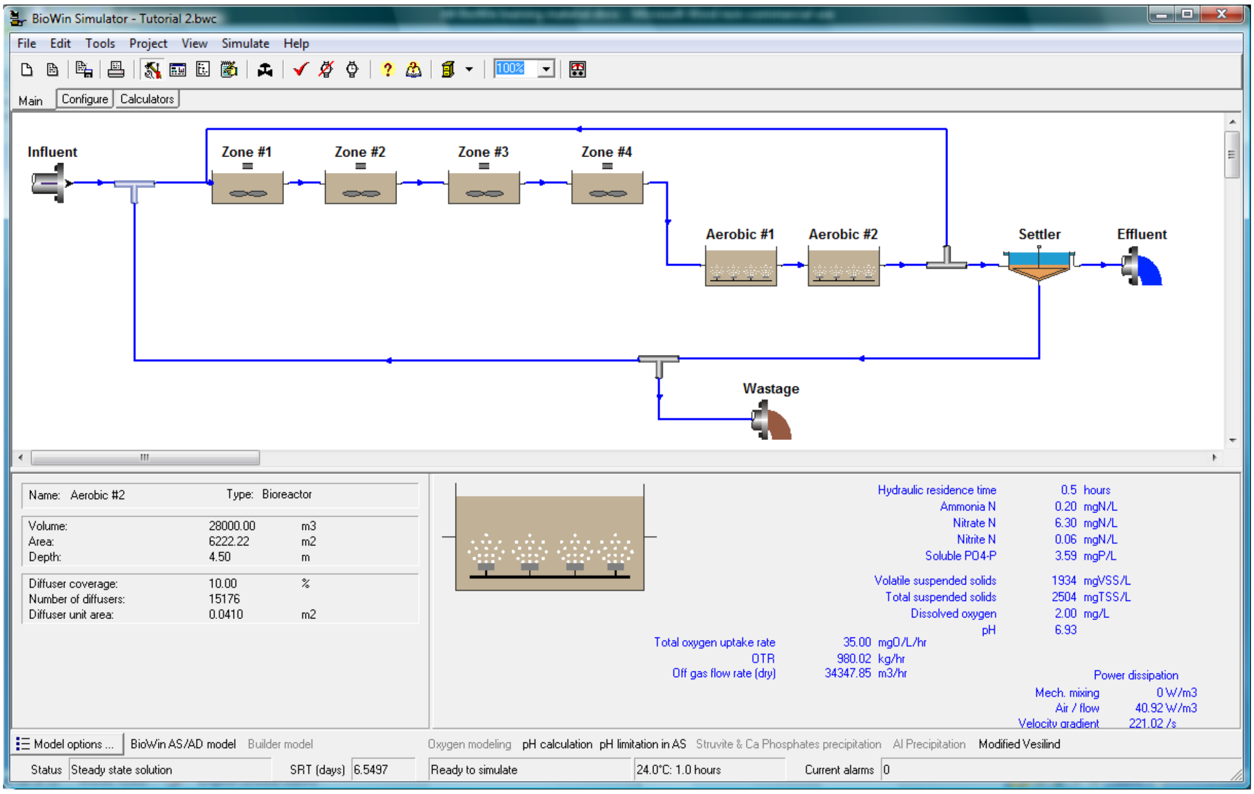

FIGURE 1. *THE CASE 2A SYSTEM CONFIGURATION.*

3 ADDING ELEMENTS TO THE DRAWING BOARD

Note: When building the configuration, don't interchange mixers (blue T) with splitters (grey T) or influents with effluents.

Note: In this case we are using an ideal secondary settler. **Case 1** used a model settler.

1. Run BioWin and change to SI units via the **Project|Current Project Options** command.
2. Add each of the units shown in the screen view above. [We'll connect units with pipes later]. Repeat the following three steps as you build the system in the drawing board:
3. Click the button corresponding to the element you want on the configuration toolbar.
4. Move the cursor onto the drawing board. When you do this, the cursor will change to the element placement cursor. Click on the drawing board where you want the element to be placed.
5. Change the names of the elements from the defaults to those shown in the screen view above (i.e. Influent, Zone #1, Zone #2,.Zone #3, Zone #4, Aerobic #1, Aerobic #2, Settler, Effluent, Wastage). Right-click on each element and select the **Name…** command from the popup menu.

Element Placement Cursor

Note: No names appear for the mixers, splitters and the settler in the screen view above. This is one of the customizable features of BioWin. You can make your own selection from the **General** tab via the **Tools|Customize** command.

Note: Your configuration may extend beyond the visible drawing board view. You may wish to change the drawing board scale from the drop down list on the toolbar.

Note: This configuration includes a mixer for the RAS stream in front of the first bioreactor. It is not necessary to include a mixer – the streams could be connected directly to the front of the bioreactor.

4 REARRANGING AND MOVING ELEMENTS ON THE DRAWING BOARD

4.1 If you want to change an element's position:

1. Click on the element selection tool from the **Configure** toolbar (or click ESC).
2. Move the cursor over the element on the drawing board you wish to move.
3. Click on the element and while holding down the mouse button, drag the element to the desired new location.

Element Selection Tool

Note: You also can move multiple elements simultaneously. Select the group of elements you wish to move, click on one of them, and drag the group to the desired new location.

4.2 If you want to change an element's vertical or horizontal orientation:

1. Click on the element selection tool from the configuration toolbar.
2. Right-click the element, and from the resulting popup menu, choose **Flip horizontal** or **Flip vertical** (the latter option only is available for elements such as splitters and mixers).

5 CONNECTING ELEMENTS WITH PIPES

1. Click the pipe tool on the **Configure** toolbar.
2. When you move the cursor onto the drawing board, the cursor will change to the "start" cursor.
3. Place the cursor over the element area where you wish the pipe to start from.
4. If the location is appropriate, a set of crosshairs will appear on the "pipe start" cursor.
5. If the location is inappropriate, the cursor will change to a circle with a slash through it to indicate that a pipe may not begin at that location.
6. Click the left mouse button once and move the cursor to the desired location of the element where you wish the pipe to end and click the left mouse button again.
7. As you move the pipe towards the element where you wish it to end, the cursor will change to the "pipe end" cursor.
8. If the location of the pipe terminus is appropriate, this cursor will remain.
9. If the location is inappropriate, the cursor will change to a circle with a slash through it to indicate that a pipe may not end at that location.
10. **Repeat steps 3-9** until you have connected all your elements with pipes.

Pipe Tool

Pipe Start Tool

Pipe Start "OK"

No Pipe Allowed

Pipe End Cursor

No Pipe Allowed

Note: To re-arrange a pipe's position, click once on the arrow head of that pipe. A series of circles appear at points along the pipe. Try dragging-and-dropping. This is important for arranging the configuration layout.

Note: Try right clicking on the arrow head of a pipe, and view the **Properties**. There are a number of options for re-arranging the pipe layout and selecting pipe style.

Specifying physical and operational data

We now wish to enter all of the physical and operational data for this system specified earlier. Each element (except influents and effluents) requires physical data, and this is specified in terms of either **Volume/Depth** or **Area/Depth**. Operational data depends on the type of element. For example, units such as bioreactors require information on aeration and DO levels. Units such as splitters and settlers also require information on the flow split in the side stream or underflow.

Note: There are many options for specifying operational data for the units in BioWin. We only touch on a few options in this case. More complete information on the different options for each unit type is provided in the "*Element Types*" chapter.

To specify data for each element (leave the influent for now):

1. Double click on the element – or click the right mouse button and select the **Properties** command. Specify data from the information listed earlier.
2. For the influent element specify the type as **Constant**. In this case we only consider steady state performance.

When you are finished use the **File|Save As…** command – or click on the Save button on the toolbar - to save the configuration as **Case 2** in the **Data/Course** directory.

File Save button

Note: Mixers and splitters can be defined as "dimensionless"; that is, nodes without volume. This is preferable to using very small volumes compared to other process units in the configuration because small volumes may result in slow dynamic simulations.

6 SPECIFYING PROCESS TEMPERATURE(S)

Specify the global temperature for the system (18°C) via the **Project|Temperature…** menu.

Note: You can specify a local temperature for many of the units. For example, view the **Operation** tab in the bioreactor dialog.

7 CHANGING MODEL PARAMETERS

In this example we must specify a maximum ammonia oxidizer (AOB) growth rate (referenced to 20°C) of 0.80 /day. All model parameters for the project are viewed/changed via the **Project|Parameters…** command. In this case we want to go to the **Kinetic** menu and change the AOB MuMax from the default of 0.90 to 0.80 /day.

Note: You can specify local model parameters for many of the units. For example, view the **Operation** tab in the bioreactor dialog and note the check box labeled **Local kinetic parameters**.

8 CHECKING THAT ALL DATA HAVE BEEN SPECIFIED

Before running a simulation BioWin must check to see that data have been specified for each of the elements.

1. Select the **Check simulate data** command from **Simulate** menu – or click on the Check data button on the toolbar. A dialog box appears with a list of elements for which data have not been specified and/or elements without pipe connections.

Check Simulate Data button

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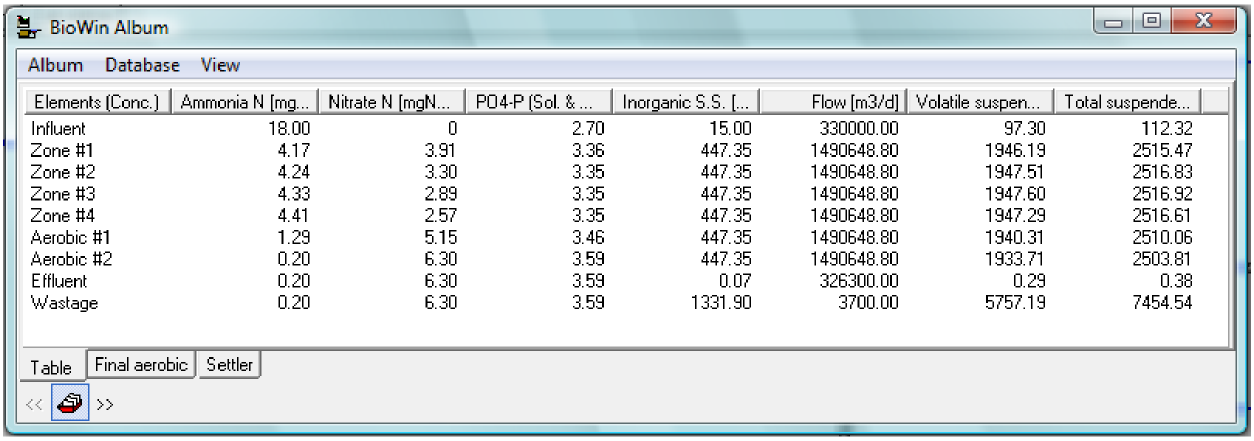
Note: Don't worry if you forget the check. BioWin will remind you about missing data. It may seem unnecessary to check data for elements (such as mixers) where you generally will accept the default values. This only is necessary once.

9 ADDING TABLES TO THE ALBUM

You've now completed setting up the configuration. [Remember: You've yet to run a simulation so data values may be garbage!]. We now want to add data tables to the Album. Let's set up a table similar to that shown below on Page 1 of the Album. This has rows for influent, all bioreactors, effluent and wastage, and columns for NH_3-N, NO_2-N, NO_3-N, NO_X-N, Soluble PO_4-P, ISS, VSS and TSS.



Elements (Conc.)	Ammonia N [mg...	Nitrate N [mgN...	PO4-P (Sol. & ...	Inorganic S.S. [...	Flow [m3/d]	Volatile suspen...	Total suspende...
Influent	18.00	0	2.70	15.00	330000.00	97.30	112.32
Zone #1	4.17	3.91	3.36	447.35	1490648.80	1946.19	2515.47
Zone #2	4.24	3.30	3.35	447.35	1490648.80	1947.51	2516.83
Zone #3	4.33	2.89	3.35	447.35	1490648.80	1947.60	2516.92
Zone #4	4.41	2.57	3.35	447.35	1490648.80	1947.29	2516.61
Aerobic #1	1.29	5.15	3.46	447.35	1490648.80	1940.31	2510.06
Aerobic #2	0.20	6.30	3.59	447.35	1490648.80	1933.71	2503.81
Effluent	0.20	6.30	3.59	0.07	326300.00	0.29	0.38
Wastage	0.20	6.30	3.59	1331.90	3700.00	5757.19	7454.54

FIGURE 4.2. TABLE FROM THE CASE CONFIGURATION.

Album button

1. Select **Album** from the **View** menu – or click on the **Album** toolbar button – or press **Ctrl + A**. This opens the **Album** – it's blank for now.
2. Select **Add Page** from the **Album** menu and click **OK**.
3. Right-click on the album page.
4. Select **Table** from the popup menu.

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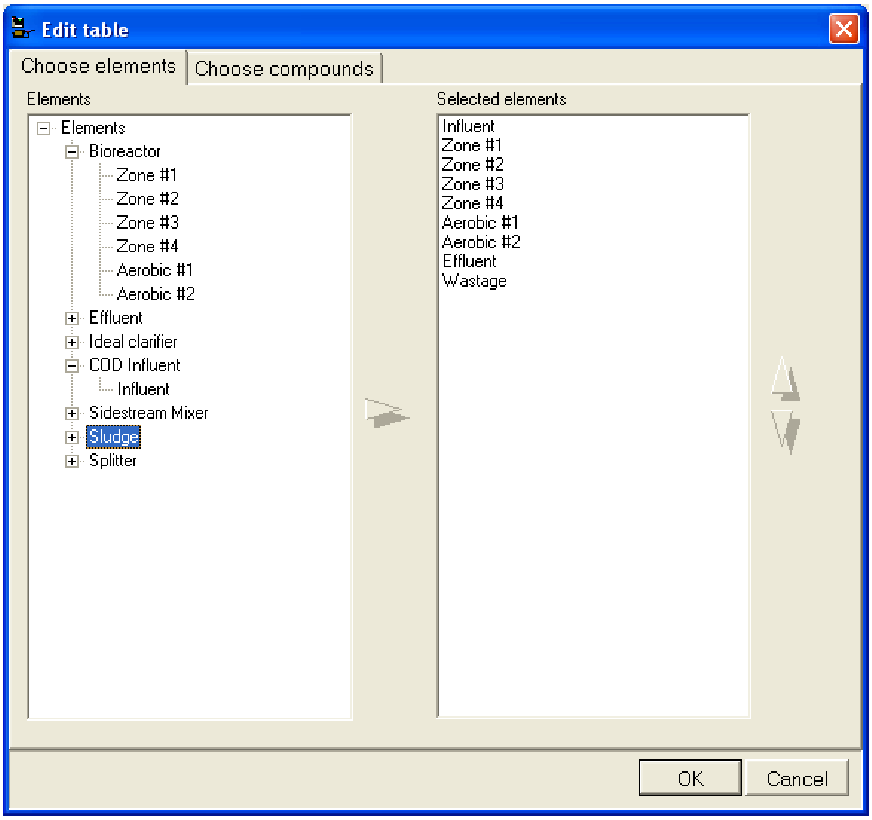

FIGURE 4.3. DIALOG BOX USED FOR CHOOSING ELEMENTS TO INCLUDE IN YOUR TABLE.

5. A dialog will open with the **Choose elements** tab displayed. From the **Elements** tree view, select the element(s) that you wish to include in the table.
6. If you wish to include all the elements from a group (for example, all the bioreactors), click on the group heading and then click the right-pointing arrow to move them all to the **Selected Elements** list.
7. If you wish to include only certain elements from a group (or groups), then click on the plus sign (+) next to the group heading to expand it, click on the specific element you want to include, and then click the right-pointing arrow to move it to the **Selected Elements** list.
8. If you want to change the order in which the **Selected Elements** will appear in the table, move the elements around by clicking on them and then clicking the **Up/Down** arrows.
9. Now click the **Choose compounds** tab. In the **Compounds** list, select the compounds that you wish to appear in your table, and add them to the **Selected compounds** list by clicking the right-pointing arrow. To select multiple compounds:
10. Select contiguous multiple compounds by clicking on the first desired compound, holding down the **Shift** key, and clicking the last desired compound.

- Select non-contiguous multiple series by holding the **Ctrl** key and clicking on the different desired compounds.

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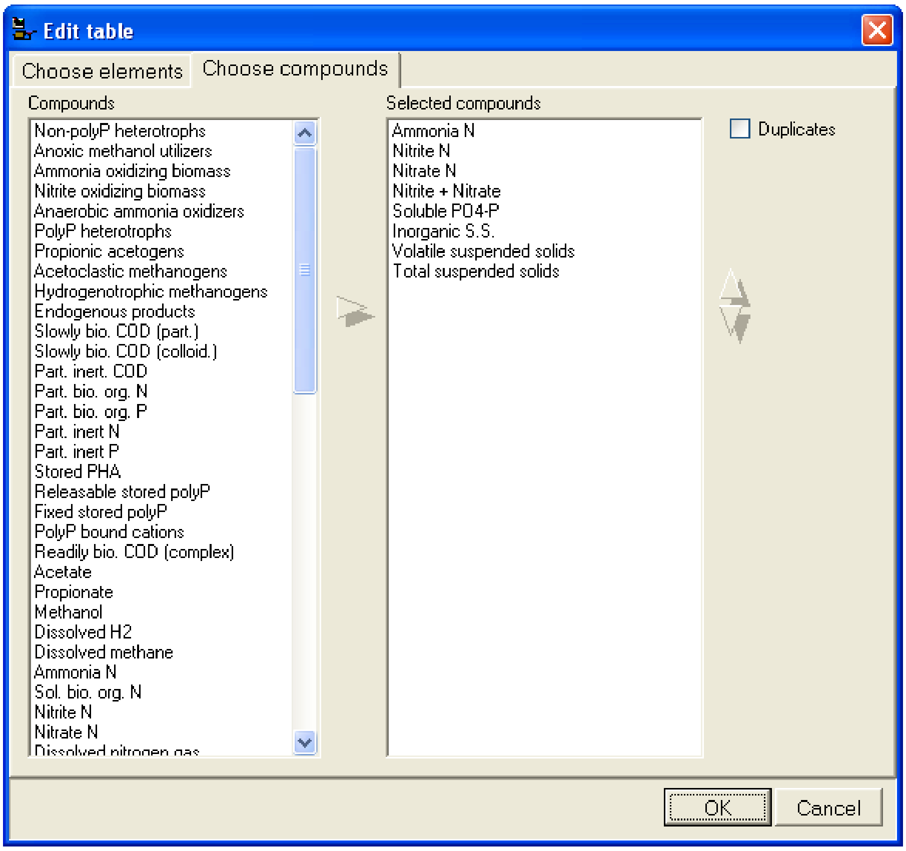

FIGURE 4. DIALOG BOX USED FOR SELECTING COMPOUNDS FOR INCLUSION IN YOUR TABLE.

11. If you wish to re-add certain compounds, place a check in the box labeled **Duplicates**, and re-add the compounds.
12. Click **OK** to finish.

Note: You can change the order of rows and columns in the table very easily. Right-click on the table, select the **Edit table** command, and use the Up/Down arrows.

Note: Try clicking the right mouse button on different parts of the **Album** pages (including the name tabs at the bottom – you can change the name of your tab to "Table" from "Page 1" if you wish).

Note: Moving the cursor over elements on the drawing board gives you a sneak preview of data in the panes below the drawing board.

---

10 ADDING ELEMENT INFORMATION TO THE ALBUM

The previous section showed how to set up a table in the Album. You can also add pre-formatted element-specific information to the Album. Let's add information on the last aerated bioreactor (Aerobic #2) to Page 2 and for the settler to a new page of the Album.

We'll do this by two different methods.

Album button

1. Select **Album** from the **View** menu – or click on the **Album** toolbar button – or press Ctrl + A.
2. Select **Add Page** from the **Album** menu and click **OK**.
3. Right-click on the album page.
4. Select **Element info** from the popup menu.
5. Select **Aerobic #2** from the drop-down element list, and click on the **Summary view** radio button.

We'll add a similar table to the Album for the settler, but using a different method.

1. Close the **Album**, and move the cursor over the settler in the drawing board.
2. Right-click and select the **Add to album|Element info (Summary)** command.
3. Select **Album** from the **View** menu – or click on the **Album** toolbar button – or press **Ctrl + A**. The new table should appear on a new Album page.

Album button

Note: Summary tables differ depending on the type of element. For example, we see an overflow rate for the settler summary and an OUR for a bioreactor. For more detailed instructions review the section on **Album Element Information Displays** in the "*BioWin Album*" chapter.

Nutrient Removal Refresher

1 INTRODUCTION

This case demonstrates application of BioWin to the system set up in Case 2A. Aspects covered in this case include phosphorus removal in an anaerobic selector, high-rate P removal systems, and high nitrification rate/high temperature conditions.

2 ANAEROBIC SELECTOR MODIFICATION (INCLUDING P REMOVAL)

File Open button

1. If you have restarted BioWin open the file **Case 2** using the **File|Open** command – or click on the **Open** button on the toolbar.
2. We'll record results in the table below:

TABLE 5.1. *AEROBIC SELECTOR MODIFICATION.*

Temp	AOB μ_{MAX}	NML Recycle	SRT	Effluent Ammonia	Effluent Nitrite	Effluent Nitrate	Effluent PO4-P

3. Run the steady state simulation. Tabulate the results, and note the nitrification, denitrification and P removal performance.
4. You also need to record the SRT. Click on the **Project|Active SRT** command – or click on the **Active SRT** button on the toolbar. You can give this SRT a name if you like (to distinguish it in case you want to look at other SRT "scenarios", *e.g.* a case where the sludge mass in the settler is included in the SRT calculation). From the **Select elements for total mass** button, add all of the bioreactors. Click the **Select wastage elements** button, expand the **Effluent** tree, and select the **Wastage** element. The SRT will now appear on the status bar at the bottom of the screen.

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5. Discuss possible retrofit options to achieve biological P removal in the existing tankage.
6. Try reducing the nitrified mixed liquor recycle rate (to zero).

Note: In specifying the wastage element(s) for the SRT calculation we selected the **Wastage output** element. We could also have selected the **side stream** (S) of the splitter where the waste stream is withdrawn. However, don't select both elements as this would count the wastage twice!

Note: We are calculating SRT based on the mass of sludge in the bioreactors. We could include the sludge in the clarifier.

Note: If we include the secondary effluent in the SRT calculation we would be accounting for solids lost via that stream.

---

3 HIGH RATE P REMOVAL SYSTEM

1. Now we wish to modify the system to attain P removal without nitrification (with the mixed liquor recycle set to zero). To do this we increase the wastage rate to reduce SRT and wash out the nitrifiers. BioWin provides a convenient way to set the SRT to a specific value, and calculate the required wastage rate.
2. Click on the **Project|Active SRT** command – or click on the SRT button on the toolbar. Place a check in the **Control SRT** box – new options appear in the lower part of the dialog.

SRT Calculation/Control

3. Select **WAS splitter** from the pull-down list, and specify the last SRT from your table. Re-run the steady state simulation, and check that the wastage rate is 3700 m^3/d.
4. Re-run for an SRT of 5 days, and tabulate the results. Reduce the SRT further to 4 days. Have we washed out the nitrifiers?

4 HIGH NITRIFICATION RATE / HIGH TEMPERATURE CONDITIONS

Now we encounter an unusually high temperature summer. What if the nitrification rate is high?

1. Change the maximum ammonia oxidizer (AOB) growth rate from the value of 0.8 to 1.0/d.
2. Change the temperature to 24°C.
3. Repeat the simulation for an SRT of 4 days, and see if the nitrifiers still wash out.
4. Decrease the SRT further to 3 days, and repeat. Is the P removal performance good?

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Nitrification Dynamics

1 INTRODUCTION

This case demonstrates dynamic simulations and a comparison of nitrification performance in a plug flow versus a completely mixed reactor configuration. We will learn how to set up charts in the Album.

Aspects covered in the case include steady state and dynamic simulations, and setting up charts in the Album.

2 THE CASE 3 SYSTEM AND THE INFLUENT DATA

For this demonstration we will split the influent flow (actual field data) equally between two parallel trains as shown in the BioWin screen view below. The system has the following characteristics:

TABLE 1. *THE CASE 3 SYSTEM*

PFR reactors:	Four (each 1.2 ML)	Depth = 4.5 m	DO = 2 mg/L
CSTR reactor:	One (4.8 ML)	Depth = 4.5 m	DO = 2 mg/L
Clarifier (Ideal):	Each	Area = 1,000 m^2	Depth = 4.8 m
Influent:	Accept default wastewater characteristics		
RAS recycle:	Each	7.5 ML/d (50%)	
Wastage rate:	Each	0.2 ML/d (constant rate)	
Temperature:	20°C		

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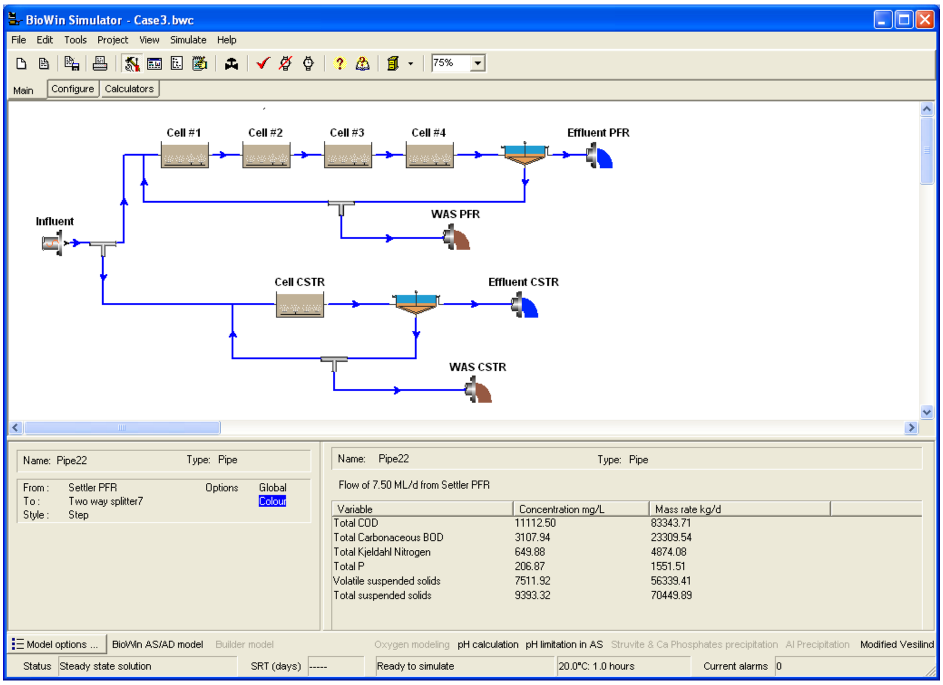


FIGURE 1. *THE CASE 3 SYSTEM CONFIGURATION LAYOUT.*

The following diurnal influent loading pattern for flow, COD, TKN, TP and ISS has been established.

TABLE 2. *THE CASE 3 SYSTEM DIURNAL INFLUENT LOADING PATTERN.*

Time	Flow (ML/d)	COD (mg/L)	TKN (mg/L)	TP (mg/L)	ISS (mg/L)
0	29.8	437	28.7	5.0	17
2	20.4	401	29.2	5.3	12
4	14.4	333	29.7	5.1	13
6	14.3	341	29.8	4.8	8
8	23.9	260	24.1	3.7	9
10	37.6	279	33.5	4.7	16
12	41.9	402	42.9	7.0	25
14	40.5	383	40.5	6.9	27
16	35.0	419	36.2	6.5	25
18	32.6	411	31.8	5.9	18
20	32.7	364	27.8	4.8	22
22	34.0	406	26.2	4.4	21

3 SET UP THE CONFIGURATION AND INFLUENT DATA

1. Select a unit basis of ML and ML/d.
2. Create the configuration shown above, and set up all of the physical and operational data.

3. Double click on the influent element, click on the **Edit data** button, and enter the time-varying influent data recorded in the table above.

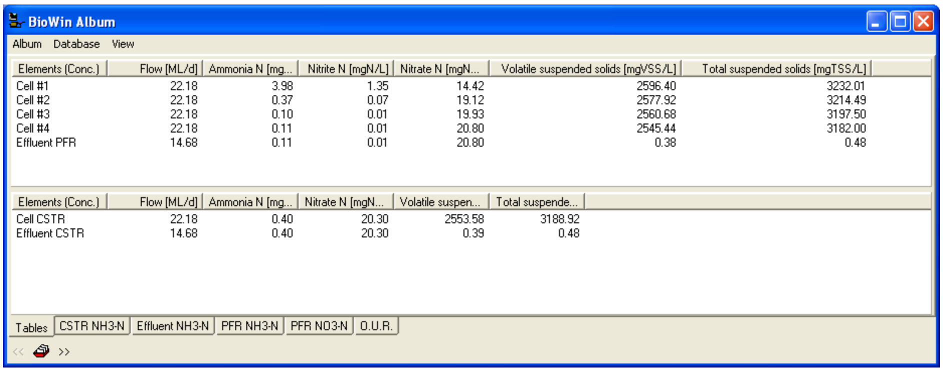
Hint: To save on typing all those numbers, find the table in the Help (Tutorials), copy columns of data to Excel, and paste the data into BioWin. When pasting a column of data, place the cursor in the top cell in a column.

4. Save the file as **Case 3** in the **Data/Course** directory.
5. Note the max. spec. growth rate from the **Project|Parameters|Kinetic** menu.

Note: In this system we do not include mixers for the influent and RAS streams. Both streams are connected directly to the front-end reactors in each train.

4 STEADY STATE PERFORMANCE

1. Run the steady state simulation.
2. Open the Album and add a new page with two horizontal panes using the **Album|Add page** command.
3. In the upper pane, set up a table that shows flowrate, NH_3-N, NO_2-N, NO_3-N, VSS and TSS for the upper section (plug flow part) of the plant; that is, in each reactor and in the effluent.
4. Create a similar table in the lower pane, but for the lower section (completely mixed).
5. Re-run the steady state simulation, and discuss the results.
6. The tables on Page 7 (note that your page number may be different if you've started with a blank album) should be similar to that shown below.



BioWin Album
Album Database View

Elements (Conc.)	Flow [ML/d]	Ammonia N [mg...	Nitrite N [mgN/L]	Nitrate N [mgN...	Volatile suspended solids [mgVSS/L]	Total suspended solids [mgTSS/L]
Cell #1	22.18	3.98	1.35	14.42	2596.40	3232.01
Cell #2	22.18	0.37	0.07	19.12	2577.92	3214.49
Cell #3	22.18	0.10	0.01	19.93	2560.68	3197.50
Cell #4	22.18	0.11	0.01	20.80	2545.44	3182.00
Effluent PFR	14.68	0.11	0.01	20.80	0.38	0.48

Elements (Conc.)	Flow [ML/d]	Ammonia N [mg...	Nitrate N [mgN...	Volatile suspen...	Total suspende...
Cell CSTR	22.18	0.40	20.30	2553.58	3188.92
Effluent CSTR	14.68	0.40	20.30	0.39	0.48

Tables | CSTR NH3-N | Effluent NH3-N | PFR NH3-N | PFR NO3-N | O.U.R.

FIGURE 7.2. *YOUR RESULTS AFTER RUNNING A STEADY STATE.*

5 SETTING UP CHARTS

There are many options for creating different types of chart in BioWin. This case will only show a few examples and a limited number of formatting options. These will be the ammonia and oxygen utilization rate responses in the system. More example charts are included in the **An Example** file. For details on charting options refer to the chapters:

- "*Creating Charts & Adding Series*"
- "*Chart Formatting Procedures*"

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- "*Series Formatting Procedures*"

Note: The default chart template can be customized.

5.1 Create a Time series chart

In this section we set up a time series chart showing the ammonia concentration response in the completely mixed reactor, Cell CSTR, and in the effluent from this train.

1. Open the Album and use the **Album|Add page** command to add a page
2. Right click on the blank pane, and select the **Chart** command.
3. Position the cursor over the chart, right click, and select **Add Series**. This opens on the **Time series** tab – the one we want for now.
4. Select **Cell CSTR** in the **Element name** pull-down list, highlight **NH3-N** from the **State variables** list, and click the **Plot selected** button. Select the **Line** option from the **Time series gallery**, and press **OK**.
5. Repeat this procedure to plot the effluent ammonia response. Select **Effluent CSTR** in the **Element name** pull-down list, highlight **NH3-N** from the **State variables** list, and click the **Plot selected** button. Select the **Line** option from the **Time series gallery**, and press **OK**.
6. Click the **Close** button in the **Add Series** dialog box.
7. On Page 2 (once again, your page numbering may be different – this is not a concern) of the Album set up a time series chart comparing the effluent ammonia concentrations for each of the two trains.

Note: No lines appear in the chart yet. You must first run a dynamic simulation (see below).

Note: Setting up charts automatically adds the plotted items to the database.

5.2 Create a Multi time series chart

In this section we set up a multi time series chart showing the ammonia concentration response in each of the reactors in the plug flow train, Cells #1 to #4. The multi time series chart is a variation of the time series where you plot the same variable in multiple zones simultaneously.

1. Open the Album and use the **Album|Add page** command to add a page
2. Right click on the blank pane, and select the **Chart** command.
3. Position the cursor over the chart, right click, and select **Add Series**. Select the **Multi time series** tab.
4. Expand the **Elements** tree in the window on the left, and move the four bioreactor cells to the right **Selected elements** list by selecting each and clicking on the right-pointing arrow. Select **NH3-N** from the **Compound** pull-down list, and click the **Plot selected** button. Select the **Line** option from the **Time series gallery**, and press **OK**.
5. Click the **Close** button in the **Add Series** dialog box.

5.3 Current value chart

1. In this section we set up a current value chart showing the nitrate concentration in each of the reactors in the plug flow train, Cells #1 to #4. A current value chart can be presented as an area, bar or pie plot.
2. Open the Album and use the **Album|Add page** command to add a page
3. Right click on the blank pane, and select the **Chart** command.
4. Position the cursor over the chart, right click, and select **Add Series**. Select the **Current value** tab.
5. Expand the tree in the **Elements** window on the left, and move the four bioreactor cells to the right **Selected elements** list. Select **NO3-N** from the pull-down **Compound** list, and click the **Plot selected** button. Select the **Bar** option from the **Current value series gallery**, and press **OK**.
6. Click the **Close** button in the **Add Series** dialog box.
7. Right click on the legend and select the **Edit Legend** command. Change the **Text** style to **Point name only**.

Note: All of the plots you have set up are 2-D at this point. However, it may be useful to change this current value plot to a 3-D plot for a presentation. On this page of the Album right click on the charts, select the **Edit Options** command and on the **3 D** sub-tab of the **Chart** tab, check the **3 Dimensions** box.

5.4 Your own time series charts

Try setting up two time series charts (line plots) on one page in the Album.

1. Open the Album and use the **Album|Add page** command to add a page. Select the layout with two horizontal panes.
2. In the upper pane set up a time series chart for the OUR (total) response for each reactor in the four-in-series reactor plug flow train.
3. In the lower pane set up a time series chart for the OUR (total) response in the single reactor completely mixed train.

6 DYNAMIC SIMULATIONS

From the main simulator window, set the dynamic simulation running for 1 day either from the **Simulate|Dynamic** simulation menu command or by clicking on the **Dynamic simulation** toolbar button. After pressing the start button select the **Start from** and **Current values** options, and a simulation time of **1 day**.

Dynamic Simulation button

1. When the dynamic simulation is complete press the stop button in the player dialog.

Note: You can switch to the Album while the simulation runs.

2. View the simulation results in the Album.

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3. Continue the simulation for another 4 days. Set the dynamic simulation running from the **Simulate/Dynamic simulation** menu command or by clicking on the **Dynamic simulation** toolbar button. After pressing the start button select the **Continue from** and **Current values** options, and set the simulation time to 4 days.
4. Open the Album while the simulation runs.
5. When the dynamic simulation is complete press the stop button in the player dialog.
6. View the results in the Album and discuss options for reducing "break-through" of ammonia.
7. Re-run the steady state simulation and then run the dynamic simulation for 2 days using the **Start from** option. When the simulation is paused at 2 days, double click on each wastage splitter in the drawing board and reduce each wastage rate from 0.2 to 0.1 ML/d. Press the start button and continue the dynamic simulation for 8 days.

Hint: Try starting a dynamic simulation by pressing the **F7** key when the **Album** is open.

7 EDITING THE CHARTS

In setting up the charts you accepted many default charting options. For example, automatic scaling of axes, the increments on axes, the grid appearance, the color selection, the legend format, the chart titles, etc. The options are too numerous to list.

Experiment with the many chart options. Start by right clicking on a chart and selecting the various commands.

Move the dialog box to one side of the chart. That way you will see the changes happen immediately without having to close the dialog.

Secondary Clarifiers

1 INTRODUCTION

This case demonstrates aspects of modeling secondary clarifier performance with the one-dimensional settler model. Aspects covered in this case include model settler behavior under steady state and dynamic conditions.

2 THE CASE 4 SYSTEM

For the demonstration we set up a simple one-reactor system with a model settler as shown in the BioWin screen view below. The system has the following characteristics:

TABLE 1. *THE CASE 4 SYSTEM.*

Bioreactor:	30 ML	Depth = 4.5 m	DO = 2 mg/L
Clarifier (Model):	Area = 4,000 m²	Depth = 4.0 m	
RAS recycle:	Initially 100 ML/d (100%)		
Wastage rate:	6 ML/d (constant rate)		

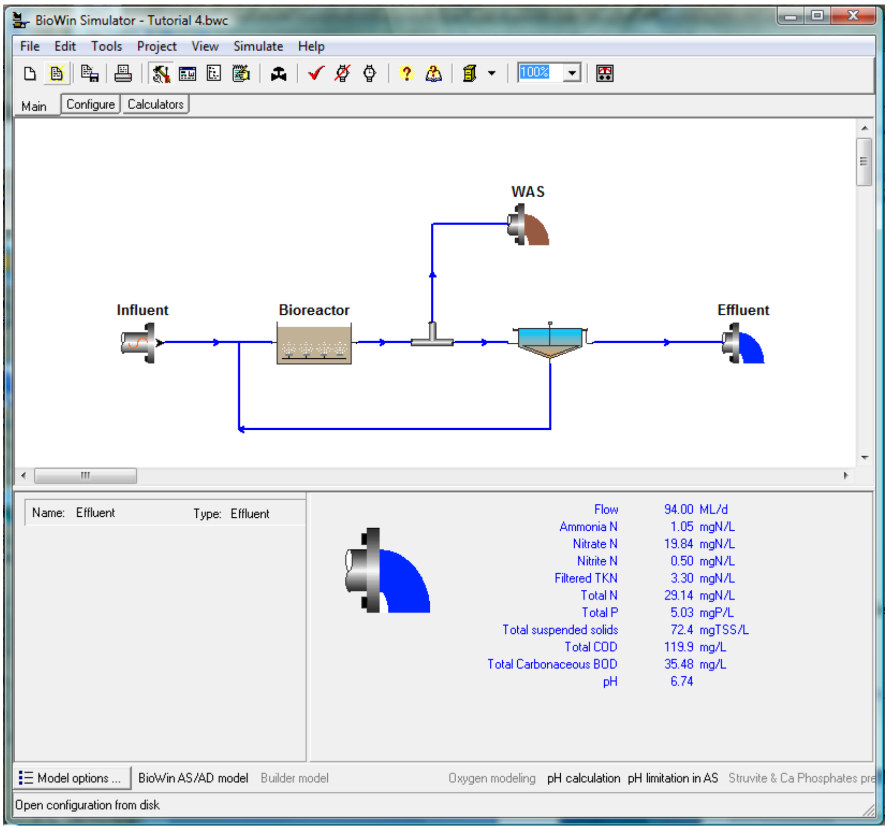

FIGURE 1. *THE CASE 4 SYSTEM CONFIGURATION.*

1. Change to SI units (ML and ML/d) and set up the system.
2. Double click on the influent element, click on the **From file** button, and load the file **An Example.ifd** from the **DATA** directory.
3. Run a steady state simulation to check that you have specified all the necessary data.
4. Use the **File|Save As** command to save the configuration as **Case 4** in the **Data/Course** directory.

Note: In this example the wastage stream effectively is withdrawn from the bioreactor, not the underflow. This is termed hydraulic SRT control. The reason for choosing this mode is that, irrespective of the underflow rate and the underflow TSS, the reactor TSS concentration will remain relatively constant. By wasting mixed liquor from the reactor we will maintain a relatively constant SRT even when the underflow rate changes. In this case wasting 6 ML/d from a bioreactor volume of 30 ML translates into a 5 day SRT (but remember we aren't accounting for sludge in the settler in this SRT calculation).

3 RECORDING RESULTS / MODIFYING THE ALBUM

1. Add a page to the Album with two vertical panes. Display the element information (summary) for the bioreactor and the model settler in the two panes. Note: this step perhaps is not necessary – you'll be able to get all the required information from the main simulator window. (TSS values, settler solids loading rate – SLR, settler specific overflow rate – SOR, etc.)
2. We'll record simulation results in the table below. All of this information can be found either in the two-pane page you added to the Album or by moving the cursor over elements in the drawing board and noting values displayed in the lower right pane.

TABLE 2 THE CASE 4 SYSTEM – RECORDING RESULTS.

Underflow Rate	Max Compactability	SLR	SOR	Effluent TSS	Reactor TSS	Underflow TSS

4 SETTING UP A SETTLER PROFILE

1. We want a view of the TSS concentration profile in the settler. Move the cursor over the settler in the drawing board, right click, and select the **Add to Album** command. Select **Profile Plot…** from the flyout menu. In the dialog highlight Total suspended solids in the right hand **Combined** list, select **Current values** for the profile type, and the **Concentration on X** orientation option. Click on the **Plot selected** button, select **Line** in the **General series gallery**, and close the dialog.

2. The preceding step generated a new plot in the Album. Open the Album – the new page should be visible.
3. You may wish to change this to a 3-D view. Right click on the chart and select the **Edit Options** command. Select the **3D** tab, and add a checkmark to the **3 dimensions** box.

Note: In this case we are simulating the settler as 10 layers in the vertical direction – numbered from top to bottom as 0 to 9.

4. While we are editing the chart we should change the bottom axis (concentration) scale to have a minimum and maximum of 15,000 mg/L, respectively. Right click on the chart and select the **Edit Axes** command. For the bottom axis, in the **Scale** tab uncheck the **Automatic** box, and use the **Change…** buttons to specify the Maximum and Minimum axis values. Press the **Close** button.

5 SETTING UP A STATE POINT CHART

1. We want add a State Point Analysis (SPA) diagram in the Album. Move the cursor over the settler in the drawing board, right click, and select the **Add to Album** command. Select **Chart…** from the flyout menu. In the dialog, select the **State point** tab. Click on the **Plot selected** button.
2. The preceding step generated a new plot in the Album. Open the Album – the new page should be visible. Edit the chart to improve the presentation.

6 STEADY STATE SIMULATIONS

1. Run the steady state simulation. Note the effluent and underflow TSS, and the SLR and SOR. View the settler profile in the Album.
2. Change the underflow rate to 50 ML/d by double clicking on the settler in the drawing board and going to the **Flow split** tab. Repeat the steady state simulation and record the results.
3. Change the underflow rate to 33 ML/d by double clicking on the settler in the drawing board and going to the **Flow split** tab. Repeat the steady state simulation and record the results.

7 DYNAMIC SIMULATIONS

1. Add a page to the Album with two horizontal panes. In the upper pane set up a time series chart (**Line** style) for the settler specific overflow rate, SOR. Set minimum and maximum values on the left axis of 0 and 20. In the lower pane set up a time series chart (**Line** style) for the settler solids loading rate, SLR. Set minimum and maximum values on the left axis of 0 and 200.

Note: Initially the charts will be blank because we have yet to run a dynamic simulation.

2. Add another page to the Album with two horizontal panes. In the upper pane set up a time series chart (**Line** style) for the effluent TSS. Set minimum and maximum values on the left axis of 0 and 30. In the lower pane set up a time series chart (**Line** style) for the settler underflow TSS. Set minimum and maximum values on the left axis of 0 and 16,000.

3. Start a dynamic simulation for 2 days. Observe the predicted performance of the model settler in the Album.

Hint: If you start the simulation from the BioWin main window the Album disappears. You can keep it open while the simulation is running if you use the F7 key to start the simulation.

4. When the simulation is paused change the RAS rate to 100 ML/d. Continue the simulation for another 3 days.
5. When the simulation is paused change the RAS rate to flow-paced at 33% (based on the influent flow). Continue the simulation for another 3 days.
6. From the **Project|Parameters|Settling...** menu, on the **Modified Vesilind** tab, change the maximum sludge compactability to 8,000 mg/L. Continue the dynamic simulation for another 6 days. Watch the settler profile and effluent TSS in the Album.
7. Try other situations with changes to the settler area/depth, and changes to the sludge settling properties.

Note: Setting a low sludge compactability may cause problems with steady state simulations not converging. This is a result of numerical solver problems because there can be multiple solutions to the mass balance equations. In this situation, what you may wish to do in place of a steady state simulation is run a dynamic simulation for an extended period of 3 - 4 SRTs. This should move to the steady state solution.

Diffused Aeration

1 INTRODUCTION

This case demonstrates diffused aeration system modeling.

Aspects covered in this case include effects of changing oxygen parameters under steady state and dynamic conditions.

2 THE CASE 5 SYSTEM

For the demonstration we will set up the simple system as shown in the BioWin screen view below. The systems have the following characteristics:

TABLE 1. *THE CASE 5 SYSTEM*

Bioreactor:	50 ML	Depth = 3.0 m	DO = 2 mg/L
Clarifier (Ideal):	Area = 4,000 m²	Depth = 4.0 m	
RAS recycle:	100 ML/d (100%)		
Wastage rate:	2.0 ML/d (constant rate)		

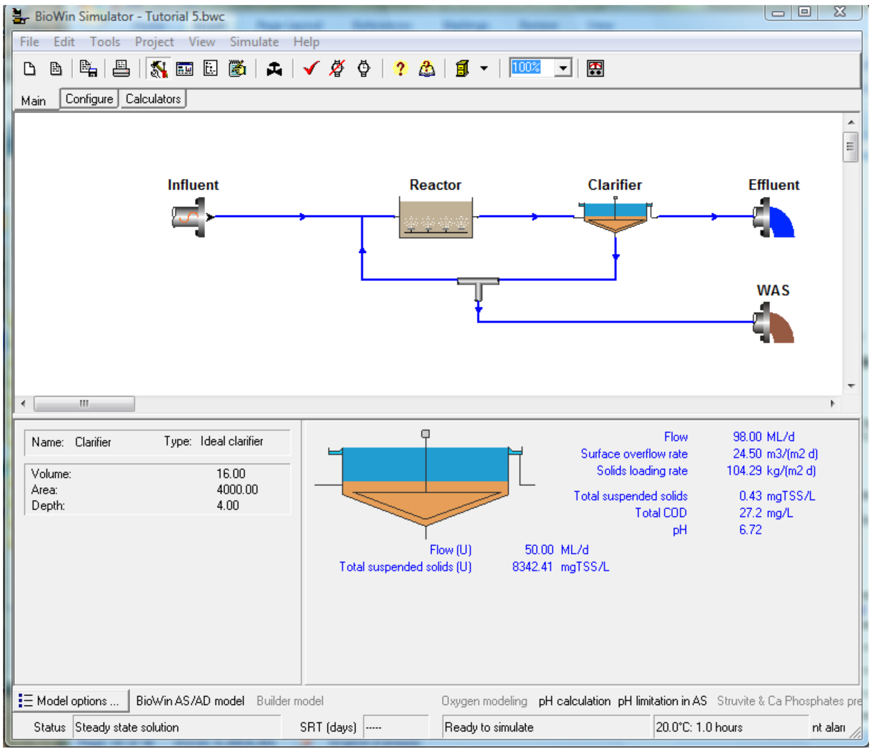

FIGURE 1. *THE SYSTEM USED FOR CASE 5.*

1. Change to SI units (ML and ML/d) and set up the system.

2. In the influent element, load the file **An Example.ifd** from the **DATA** directory
3. Use the **File|Save As** command to save the configuration as **Case 5** in the **Data/Course** directory.

3 RECORDING RESULTS AND MODIFYING THE ALBUM

1. Add a new page to the Album. Display the element information (summary) for the bioreactor.
2. We'll record simulation results in the table below. All of this information can be found in the page you added to the Album.

TABLE 2. *THE CASE 5 SYSTEM – RECORDING RESULTS.*

Depth	Temp.	αF	DO	OUR	Q_{AIR}	OTR	SOTE(%)
3.0	20	0.5	2				
4.5	20	0.5	2				
6.0	20	0.5	2				
4.5	12	0.5	2				
4.5	20	0.5	4				
4.5	20	0.8	2				

4 STEADY STATE SIMULATIONS

1. Run a steady state simulation and evaluate the predicted performance of the aeration system. Tabulate the results.
2. Change the depth of the reactor in steps from 3.0 m to 4.5 and then 6.0 m. For each change, re-run the steady state simulation, and tabulate the results for the new depth.
3. Set the depth of the bioreactor to 4.5 m. The global temperature for the system is 20°C. Double click on the bottom cell to open the **Properties** dialog. On the **Operation** tab, check the local temperature option, and specify a temperature of 12°C. Re-run the steady state simulation, and tabulate the results for the new temperature.
4. Re-set the temperature to 20°C. Change the DO setpoint in the bioreactor to 4 mg/L, re-run the steady state simulation, and tabulate the results.
5. Re-set the DO setpoint to 2 mg/L in the reactor. Change α for the reactor to 0.8 (double-click on the reactor, click the **Operation** tab, check the **Local aeration parameters box** and click the **Model Parameters** button – you can find aeration parameters such as alpha and beta on the **Aeration** tab). Re-run, and tabulate the results.
6. Switch on oxygen transfer and DO modeling in the **Project|Current Project Options** menu on the **Model** tab. Re-run the steady state simulation, and discuss differences in model predictions.

7. Re-set the α value to 0.5. Instead of specifying a DO setpoint, switch to air supply rate and adjust the value.

5 DYNAMIC SIMULATIONS

1. Modify the Album to include charts of air supply rate, DO and OURt for each of the aerated reactors.
2. Start a dynamic simulation. Observe the response of the aeration parameters.
3. Pause the simulation and change aeration parameters. Attempt to predict the effect of the change before continuing the simulation.

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Plant Calibration Exercise

1 OBJECTIVES

The objectives of this calibration example are:

1. To help the user gain experience with modeling using BioWin;
2. To explain how BioWin uses plant data that are typically available;
3. To provide a case where BioWin helps to verify data integrity (i.e. finding errors in measurements);
4. To show how the data can be used to calculate necessary input parameters (influent fractions) for the model;
5. To familiarize users with a step-by-step calibration approach.

2 THE CASE 6 SYSTEM – PLANT SPECIFICATION AND DATA

This municipal plant has one process line that consists of a primary settler (represented by an Ideal Primary Tank), two activated sludge bioreactors in series, a final clarifier (Ideal Clarifier), recycle to the first bioreactor, and wastage from the RAS recycle. The plant can be operated in nitrifying mode only (both reactors aerated), or in denitrifying mode, if the first tank is converted into an anoxic zone.

TABLE 1. *PLANT PHYSICAL DIMENSIONS.*

Unit	Area m^2	Volume m^3	Depth m
Primary settler	600		4.0
Bioreactor #1		4200	4.0
Bioreactor #2		6000	4.0
Final clarifier	12000		4.3

The plant was operated in fully aerobic (nitrifying) mode. Long term daily average data for model calibration were extracted from plant operations spreadsheets. The data set represents 3 months' daily values with the impact of storms and process upsets already removed from the database. Plant flows are listed in Table 2, influent concentrations in Table 3, and other plant measured data in Table 4.

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TABLE 2. *PLANT FLOWS AND OPERATIONAL DATA.*

Unit	Value	Units
Influent	28400	m3/d
Primary sludge flow	110	m3/d
Final clarifier underflow	21300	m3/d
Wastage	950	m3/d
DO in tank #1	1.8	gO2/m3
DO in tank #2	2.2	gO2/m3
Process temperature	18	°C

TABLE 3. *PRIMARY INFLUENT CONCENTRATIONS.*

Parameter	Value	Units	Note
Total COD	467	mgCOD/L	Enter into influent form
CODs (GFC)	210	mgCOD/L	Use in fractionation
FF CODs	92	mgCOD/L	Use in fractionation
TKN	30.5	mgN/L	Enter into influent form
TP	6.1	mgP/L	Enter into influent form
PO4-P	2.5	mgP/L	Use in fractionation
Alkalinity	265	mgCaCO3/L	Enter into influent form
pH	7.0	pH units	Enter into influent form
TSS	204	mgTSS/L	Use in fractionation
VSS	171	mgVSS/L	Use in fractionation
Ammonia	23.6	mgN/L	Use in fractionation
cBOD5	234	mgO2/L	Use in fractionation

TABLE 4. *PLANT DATA AND WORKSHEET*

	Units	Measured	Run #1	Run #2	Run #3	Run #4
Main parameter changed			Influent fractions	Primary calibration	Secondary % removal	Wastage
New parameter value						
Primary effluent TSS	mgTSS/L	84.1				
Primary effluent BOD	mgO_2/L	164.0				
Primary sludge concentration	mgTSS/L	17700				
MLSS	mgTSS/L	1910				
MLVSS	mgVSS/L	1580				
Effluent TSS	mgTSS/L	14.2				
Effluent total COD	mgCOD/L	48.1				
Effluent filtered COD	mgCOD/L	31.0				
Effluent BOD	mgO2/L	6.0				
Effluent ammonia	mgN/L	0.2				
Effluent NO3	mgN/L	14.5				
Effluent PO4-P	mgP/L	2.4				
Effluent Alkalinity	$mgCaCO_3/L$	123				
Wastage/Recycle TSS	mgTSS/L	4510				

3 PLANT MODEL CONFIGURATION

Set up the model in BioWin.

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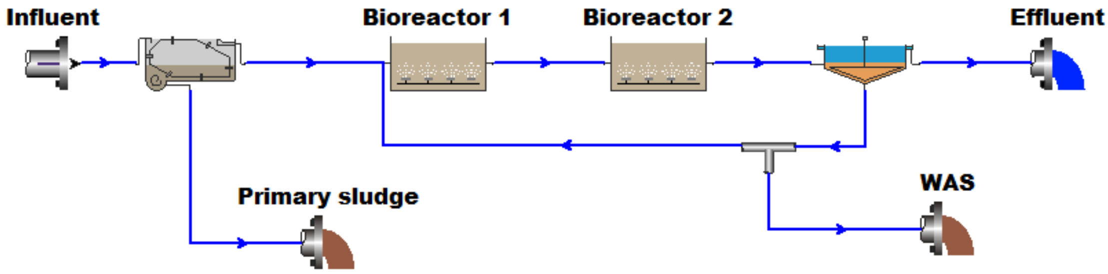

FIGURE 1. *PLANT MODEL CONFIGURATION.*

Enter physical, operational and influent concentration data, but leave all other parameters, influent fractions, etc. at their default values. Simulate steady-state conditions. Compare your results with the laboratory values in Table 8. Keep in mind that all measurements carry an experimental error and some measurements (two in this case) can be suspect, involving a large error. Discuss results with the class.

4 CALIBRATION STEPS

4.1 Set up influent fractions

Use the Influent **Specifier Raw 3_0.xls** spreadsheet provided.

1. On Tab "**Step 1 - Input Measurements**", enter the available measured data (in red color) from Tables 3. Look at calculated fractions to the right of the measurements on the same tab to get a feeling which measurement affects which fraction.
2. On Tab "**Step 2 - Estimate COD fractions**" change fractions (in red color) until you achieve excellent or acceptable matches with measurements.
3. Go to Tab "**Step 3 – Copy to BioWin**" and copy – paste the fractions into the appropriate BioWin influent form.
4. Run steady-state (F6). Record the main fractions you used below in Table 5.
5. Discuss results with the class **[Run 1]**.

TABLE 5. *INFLUENT FRACTIONS IN BIOWIN.*

Parameter	Default	Value used	Explanation
Fbs	0.16		From Influent Specifier (FFCOD-Sus)/TCOD)
Fac	0.15		VFAs important only for BNR plants. Use zero or default
Fxsp	0.75		From Influent Specifier – to match solids and FFCOD
Fus	0.05		From effluent CODs / influent CODt
Fup	0.13		From Influent Specifier match
Fna	0.66		Ammonia / TKN
Fnox	0.50		Not a sensitive parameter – leave at default
Fnus	0.00		Low concentration – leave at default
FupN	0.035		Leave at default
Fpo4	0.50		PO_4-P / TP
FupP	0.011		Leave at default

4.2 Primary clarifier calibration

1. Primary effluent values will influence the biological stage and must be properly calibrated first before moving on to the downstream processes.
2. Calculate primary effluent percent solids removal – input in BioWin.
3. Check primary effluent solids to verify correct results. Adjust if necessary**.**
4. Check the simulated vs. measured raw sludge concentration. If there is a large error, perform a mass balance around the primary ***using measured data***, adjust raw sludge flow to close mass balance, using Table 6 as an aid. (**Hint** – alternatively as a quick approximation, the simulated/measured concentration ratio can effectively be used to adjust the raw sludge flow) **[Run 2].**

TABLE 6. *MASS BALANCE AROUND PRIMARY CLARIFIER.*

Stream	Flow m^3/d	TSS mg/L	Mass rate kg/day (Measured data)	Mass rate kg/day (Adjusted raw sludge flow = ? m^3/d)	Note
Influent					
Primary effluent					
Raw sludge					
Balance*		N/A			

* Balance = IN – OUT = Influent – (Effluent + Raw Sludge)

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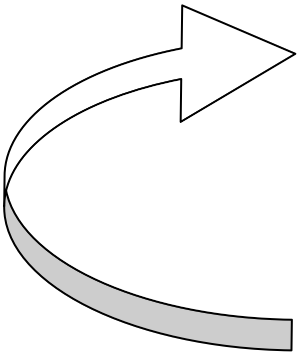
4.3 Final clarifier calibration



1. Adjust **final clarifier** percent removal to match effluent solids **[Run 3]**.
2. **Check MLSS.** If the match is not good, suspect waste flow measurement error - adjust wastage flow to match MLSS. (A more rigorous way to check waste flow data is to perform a check on inorganic suspended solids or P balance around the activated sludge plant (assuming no other sources of inorganic solids are present like precipitation or Poly-P).
3. Check **effluent quality**. If the model is constructed properly, effluent BOD should be low. Return to adjusting effluent solids if necessary **[Run 4]**.

4.4 AOB growth rate (match effluent ammonia)

1. The plant is in summer conditions (18°C), and only effluent ammonia measurements are available. The effluent is fully nitrified in summer and it does not contain enough information to establish the growth rate parameter. Try a few different growth rates and see how it affects effluent ammonia under these conditions. Use Table 13.6 to record growth rates and simulation results.
2. Now we have effluent and Tank 1 ammonia measurements available in winter (10°C). Under these conditions the plant is partially nitrifying and the growth rate can be more accurately determined using an assumed temperature dependency (leave at default, 1.096).
3. If we had dynamic information, the accuracy of estimation would improve. The best solution is to perform nitrification rate measurements as mentioned elsewhere (High F/M or Washout test).

TABLE 7. *NITRIFICATION RATE CALIBRATION.*

Parameter	Units	Step #1	Step #2	Step #3	Step #4	Step #5
AOB growth rate	1/d					
Temperature	°C	18	18	18	10	10
Measured Effluent NH_3	mgN/L	**0.2**	**0.2**	**0.2**	**3.7**	**3.7**
Simulated Effluent NH_3	mgN/L					

5 RESULTS

Record your final simulation results in Table 7 **[Run 8]**. Record your final calibrated parameter values in the table below.

TABLE 8. *CALIBRATION RESULTS – INITIAL AND FINAL.*

Parameter	Units	Initial value	Calibrated value
Primary % removal	%	65	
Raw sludge flow	m^3/d	110	
Secondary % removal	%	99.8	
Wastage flow	m^3/d	950	
AOB growth rate	1/d	0.9	

6 OTHER OPTIONAL EXERCISES

This section provides further exercises that help to improve your understanding of the model and sensitivity to various model inputs

1. **Denitrification**: Turn Tank #1 into anoxic mode. Investigate the change in effluent quality and the sensitivity of denitrification to:
    1. anoxic volume,
    2. soluble biodegradable COD fraction (f_{BS}),
    3. anoxic hydrolysis factor (Neta Anox Hyd),
    4. anoxic yield.
    5. various nitrate recycle flows from Tank #2 to Tank #1
2. **Diurnal runs**. Use a diurnal profile and run several days dynamically after steady state. Check how the steady state effluent values match with diurnal peak and average values.
3. **Alkalinity limitation**. In the previous simulations there was enough alkalinity in the influent wastewater for complete nitrification. Lower the influent alkalinity in the fully aerobic (nitrifying) plant and see how it affects effluent ammonia. Can alkalinity recovered in denitrification improve nitrification?

Advanced Features in BioWin

The latest version of BioWin provides a host of additions and improvements to enhance your wastewater treatment plant simulations such as:

- Biofilm model
- Two-step nitrification and denitrification
- Anammox bacteria
- MBRs

Incorporation of two-step nitrification and denitrification and the growth of Anammox bacteria enhance the capacity of BioWin for detailed modeling of the various sidestream (e.g. digester centrate) treatment systems that have been developed in recent years.

This section briefly reviews some of the useful features that may be overlooked in BioWin.

1 THE INTERFACE

The BioWin interface ha sshortcuts displayed on the menu bar which change, depending on which tab is selected.

- **Main tab :** Simulations are run from the **Main** tab.
- **Configure tab :** The **Configure** tab is selected when setting up a system.
- **Calculator tab :** Several SRT calculators can be configured via the **Calculators** tab. The one designated as the 'active' SRT is displayed on the status bar at the bottom of the screen.

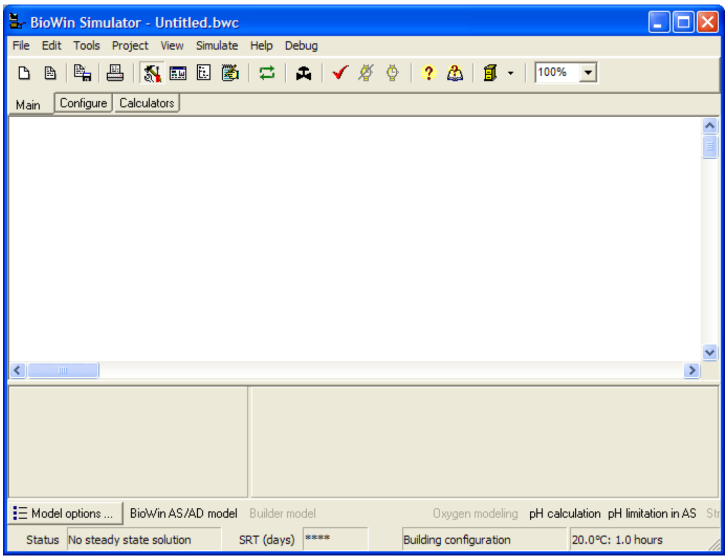


FIGURE 1. *THE BIOWIN INTERFACE.*

A useful feature added to the interface is that information on streams (flow, concentration and mass rate) is displayed in the lower right pane when you point at pipes:

Name: Pipe15 Type: Pipe

Flow of 2.00 ML/d from WAS splitter

Variable	Concentration mg/L	Mass rate kg/d
TCOD	8785.80	17571.60
TCBOD	2846.75	5693.51
TKN	503.87	1007.74
TP	306.87	613.73
VSS	5923.28	11846.55
TSS	7956.89	15913.77

BioWin is installed with a number of pre-configured systems (and Albums). These can be accessed from the Cabinet button.

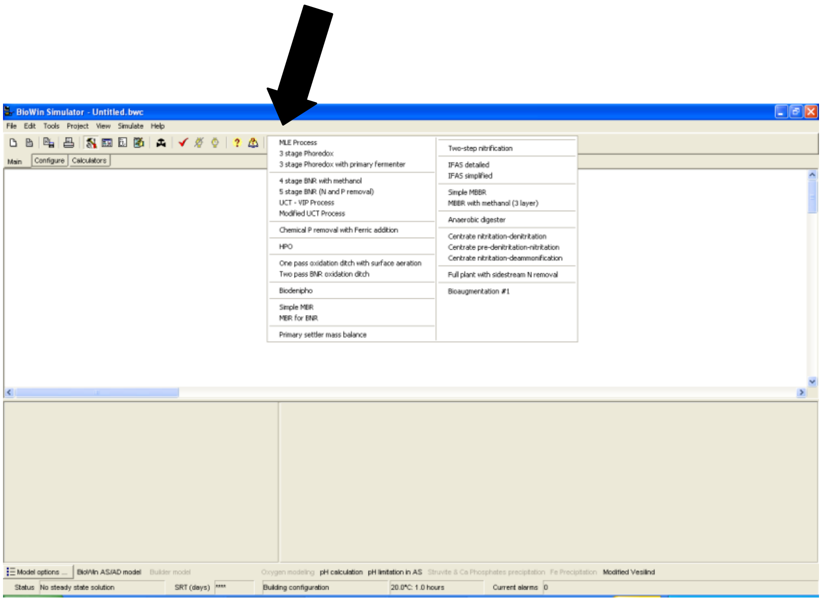
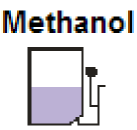


FIGURE 2. *OPENING THE CABINET PROVIDES A NUMBER OF PRE-CONFIGURED SYSTEMS.*

2 NEWER ELEMENTS IN BIOWIN

A number of the newer elements in BioWin include:

- **Methanol input**



A specific methanol-utilizing biomass, Z_{BMETH}, is included in the model.

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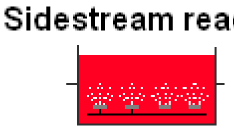
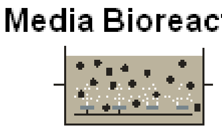
- Sidestream bioreactor

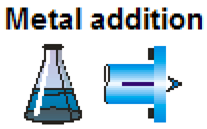


Note: The Sidestream Reactor element has been added mainly for convenience as it is easily distinguished from other activated sludge reactors on the drawing board. The model applied in a sidestream reactor is no different from the model used in other units. BioWin is based on a single integrated model for all biological and chemical reactions, and the same model is applied to any unit in a BioWin simulation. The only difference for a Sidestream Reactor is that the "seed" values selected by BioWin when a simulation starts differ from those for a standard activated sludge bioreactor.

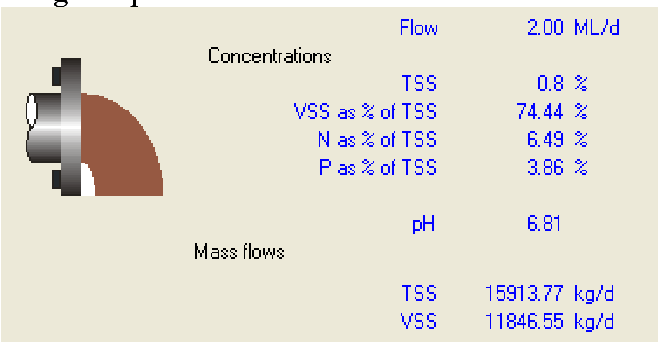
- **Media bioreactor** (for IFAS and MBBR systems)



- **Metal addition input** (for ferric or alum addition)

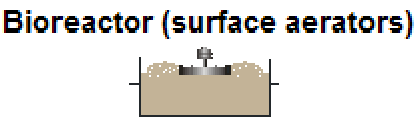


- **Sludge output**



- **Brush aerator bioreactor**

- **Surface aerator bioreactor**



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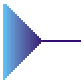
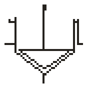
- **General mixer** (for combining multiple streams)



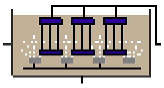
- **Point clarifier**



This phase separation element is a simplification of the ideal settler - it has no volume. Fractional solids removal is applied and the remaining solids are instantly returned in the underflow. Typical uses for this element:

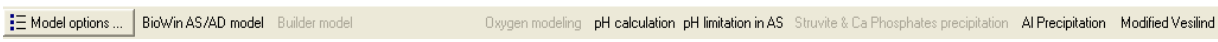
- Dewatering units and other phase separation elements that contain a negligible volume of sludge (much faster run time compared to the dewatering unit with volume in Version 1.2. In later versions dewatering units have no volume either).
- Simple simulations (faster model than the ideal settler, but ignores sludge volume).
- Verifying simulations done in other packages or using international models (SSSP, and the ASM model set).

- **Membrane Bioreactor**



3 MODEL OPTIONS

Model options can be switched on and off as required for a specific system. For example, if no ferric salts or alum are added to a particular system, then there is no necessity to include simulation of this model component. The current status of the selected model options is displayed in a bar along the bottom of the screen immediately above the status bar.



Clicking on the **Model options** button on the left opens a dialog where the user can switch options on and off:

- **BioWin integrated AS/AD model**: This is the default activated sludge and anaerobic digestion biological model.
- **Project Model Builder model**: This option is selected if (a) an add-on to the BioWin model is to be included, or (b) if the BioWin integrated AS/AD model is to be replaced by an alternative model such as ASM1, ASM2d or ASM3.
- **Oxygen modeling**: If this option is **not** selected, it is assumed that there is an immediate response to DO setpoint changes (i.e. without a lag in response). Whether this option is on or off, within bioreactors BioWin accounts for additional aeration requirements to raise the DO of input streams to the reactor DO.

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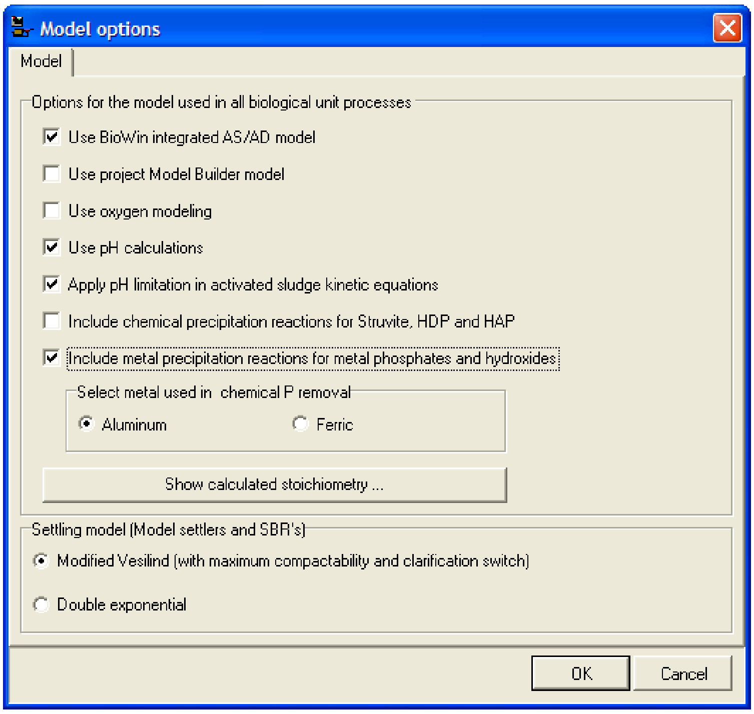
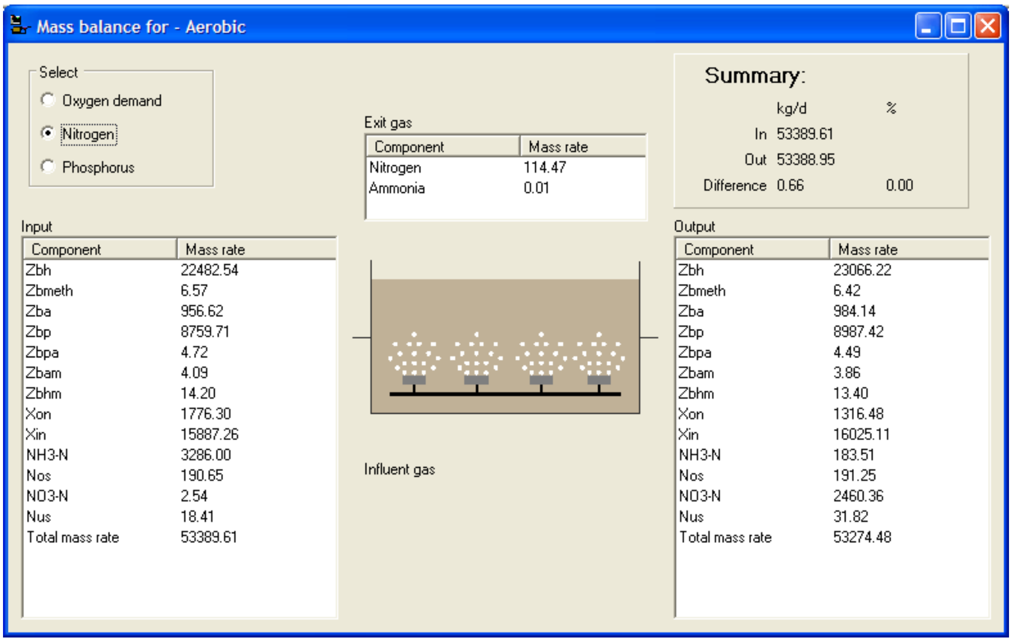
- **pH calculations**: pH in all units and streams is calculated when this option is selected; otherwise pH 7 is assumed (pH in digesters can be specified separately).
- **Apply pH limitation in activated sludge kinetic equations**: pH dependency of activated sludge kinetic equations is accounted for when this option is selected. In anaerobic digesters pH dependency is always applied.
- **Chemical precipitation reactions for Struvite, HDP and HAP**: This option must be selected to model potential precipitation of struvite ($MgNH_4PO_4.6H_2O$), HDP (hydroxy-dicalcium-phosphate – $Ca_2HPO_4(OH)_2$) and HAP (hydroxy-apatite – $Ca_5(PO_4)_2OH$). pH calculations must be selected.
- **Metal precipitation reactions for metal phosphates and hydroxides**: This option should be selected for chemical phosphorus precipitation with ferric or alum addition. pH calculations must be selected.
- **Settling model** (applied in model settlers and SBRs): The modified Vesilind (maximum compactability and clarification switch) or the Double Exponential model can be selected.



4 MASS BALANCE INFORMATION ON SPECIFIC ELEMENTS

Right click on an element, and select the Mass Balance option.



Mass balance for - Aerobic

Select: Oxygen demand / Nitrogen (selected) / Phosphorus

Exit gas

Component	Mass rate
Nitrogen	114.47
Ammonia	0.01

Summary:

	kg/d	%
In	53389.61	
Out	53388.95	
Difference	0.66	0.00

Input

Component	Mass rate
Zbh	22482.54
Zbmeth	6.57
Zba	956.62
Zbp	8759.71
Zbpa	4.72
Zbam	4.09
Zbhm	14.20
Xon	1776.30
Xin	15887.26
NH3-N	3286.00
Nos	190.65
NO3-N	2.54
Nus	18.41
Total mass rate	53389.61

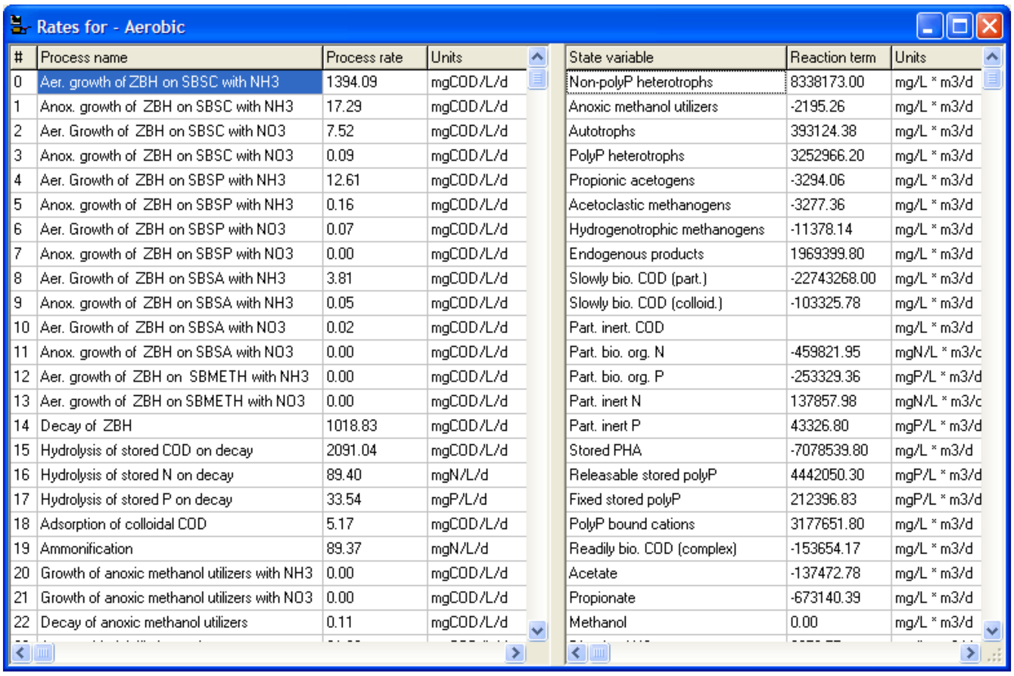
Influent gas

Output

Component	Mass rate
Zbh	23066.22
Zbmeth	6.42
Zba	984.14
Zbp	8987.42
Zbpa	4.49
Zbam	3.86
Zbhm	13.40
Xon	1316.48
Xin	16025.11
NH3-N	183.51
Nos	191.25
NO3-N	2460.36
Nus	31.82
Total mass rate	53274.48

5 KINETIC/RATE INFORMATION ON SPECIFIC ELEMENTS

Right click on an element, and select the Rates option.



Rates for - Aerobic

#	Process name	Process rate	Units
0	Aer. growth of ZBH on SBSC with NH3	1394.09	mgCOD/L/d
1	Anox. growth of ZBH on SBSC with NH3	17.29	mgCOD/L/d
2	Aer. Growth of ZBH on SBSC with NO3	7.52	mgCOD/L/d
3	Anox. growth of ZBH on SBSC with NO3	0.09	mgCOD/L/d
4	Aer. Growth of ZBH on SBSP with NH3	12.61	mgCOD/L/d
5	Anox. growth of ZBH on SBSP with NH3	0.16	mgCOD/L/d
6	Aer. Growth of ZBH on SBSP with NO3	0.07	mgCOD/L/d
7	Anox. growth of ZBH on SBSP with NO3	0.00	mgCOD/L/d
8	Aer. Growth of ZBH on SBSA with NH3	3.81	mgCOD/L/d
9	Anox. growth of ZBH on SBSA with NH3	0.05	mgCOD/L/d
10	Aer. Growth of ZBH on SBSA with NO3	0.02	mgCOD/L/d
11	Anox. growth of ZBH on SBSA with NO3	0.00	mgCOD/L/d
12	Aer. growth of ZBH on SBMETH with NH3	0.00	mgCOD/L/d
13	Aer. growth of ZBH on SBMETH with NO3	0.00	mgCOD/L/d
14	Decay of ZBH	1018.83	mgCOD/L/d
15	Hydrolysis of stored COD on decay	2091.04	mgCOD/L/d
16	Hydrolysis of stored N on decay	89.40	mgN/L/d
17	Hydrolysis of stored P on decay	33.54	mgP/L/d
18	Adsorption of colloidal COD	5.17	mgCOD/L/d
19	Ammonification	89.37	mgN/L/d
20	Growth of anoxic methanol utilizers with NH3	0.00	mgCOD/L/d
21	Growth of anoxic methanol utilizers with NO3	0.00	mgCOD/L/d
22	Decay of anoxic methanol utilizers	0.11	mgCOD/L/d

State variable	Reaction term	Units
Non-polyP heterotrophs	8338173.00	mg/L * m3/d
Anoxic methanol utilizers	-2195.26	mg/L * m3/d
Autotrophs	393124.38	mg/L * m3/d
PolyP heterotrophs	3252966.20	mg/L * m3/d
Propionic acetogens	-3294.06	mg/L * m3/d
Acetoclastic methanogens	-3277.36	mg/L * m3/d
Hydrogenotrophic methanogens	-11378.14	mg/L * m3/d
Endogenous products	1969399.80	mg/L * m3/d
Slowly bio. COD (part.)	-22743268.00	mg/L * m3/d
Slowly bio. COD (colloid.)	-103325.78	mg/L * m3/d
Part. inert. COD		mg/L * m3/d
Part. bio. org. N	-459821.95	mgN/L * m3/c
Part. bio. org. P	-253329.36	mgP/L * m3/d
Part. inert N	137857.98	mgN/L * m3/c
Part. inert P	43326.80	mgP/L * m3/d
Stored PHA	-7078539.80	mg/L * m3/d
Releasable stored polyP	4442050.30	mgP/L * m3/d
Fixed stored polyP	212396.83	mgP/L * m3/d
PolyP bound cations	3177651.80	mg/L * m3/d
Readily bio. COD (complex)	-153654.17	mg/L * m3/d
Acetate	-137472.78	mg/L * m3/d
Propionate	-673140.39	mg/L * m3/d
Methanol	0.00	mg/L * m3/d

6 CUSTOMIZING BIOWIN

Various features can be customized via the **Tools/Customize** and **Tools/New Project Options** menu. For example, you can select to display either full names or abbreviated (cryptic) descriptions for the many parameters. These selections are persistent once BioWin is restarted.

Certain features can also be customized for the current project via the **Project/Current Project Options** menu.

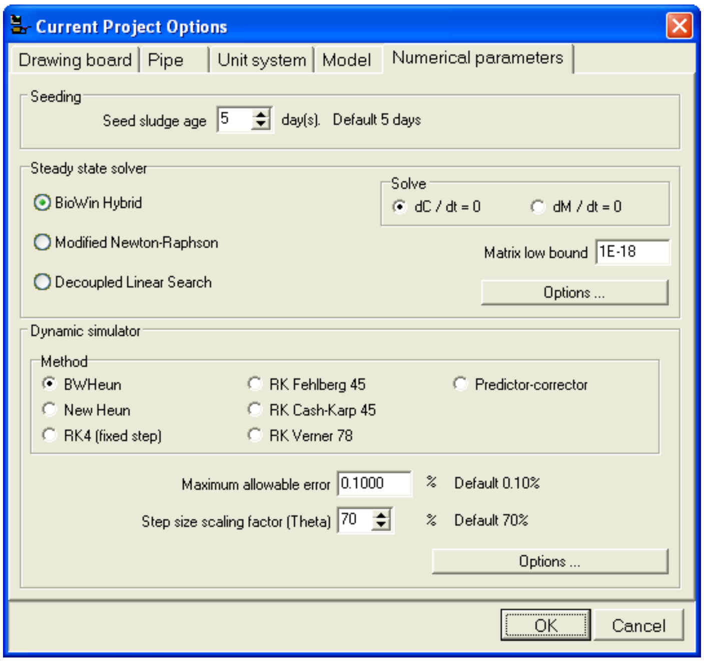
7 NUMERICAL SOLVER SETTINGS

The solver for steady state simulations has been refined. The default solver (BioWin Hybrid) uses a combination of Newton-Raphson and Decoupled Linear Search (DLS) numerical methods. Typically steady state solutions are found in 5 to 12 iterations. Nevertheless, with certain configurations the solver may encounter difficulties in converging to a solution. The on-line Help and the printed manual include a section on **Managing BioWin Projects/ Numerical parameters/ Tips for systems that are difficult to solve**.

Four approaches for resolving problem situations are suggested below.

7.1 Decoupled linear search

For very large systems (particularly those including multiple model clarifier units) try selecting the **Decoupled linear search** solver via the **Project/Setting Project Options/Current Project Options/ Numerical parameters** menu.



7.2 Conservative solver settings

If the Error value displayed in the **Steady state analysis** window does not decrease from iteration to iteration after say 15 or 20 iterations, try selecting conservative solver settings. From the **Project/Current Project Options/ Numerical parameters** menu, click on the **Options** button in the **Steady state solver method** section, and click on the **Set conservative defaults** button. This change may result in slow solver convergence, but often will improve solver stability (the Error value should decrease from iteration to iteration).

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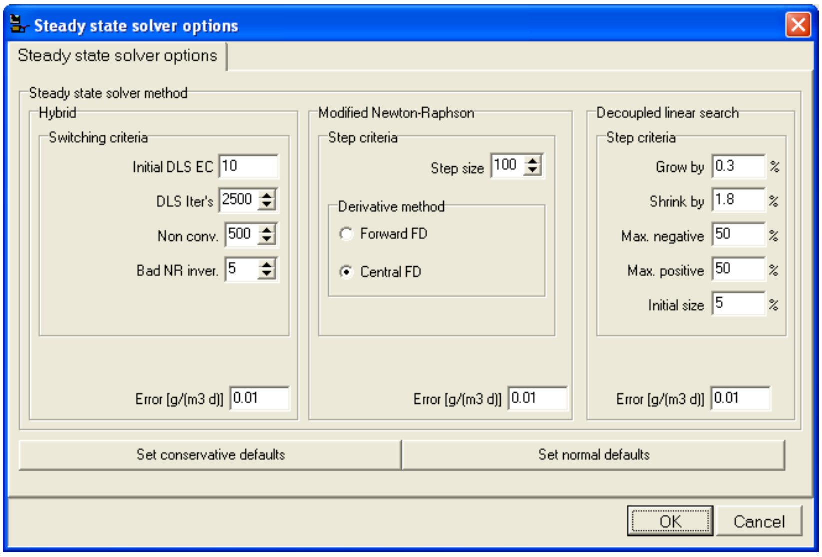
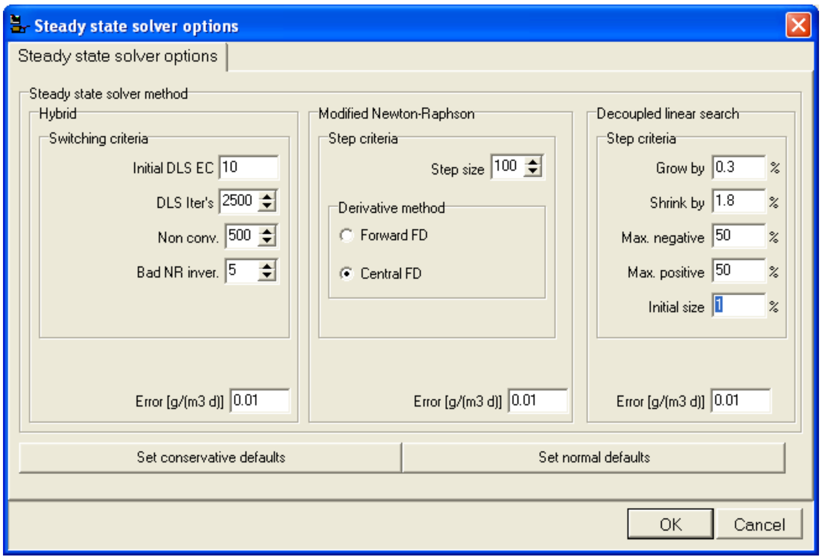


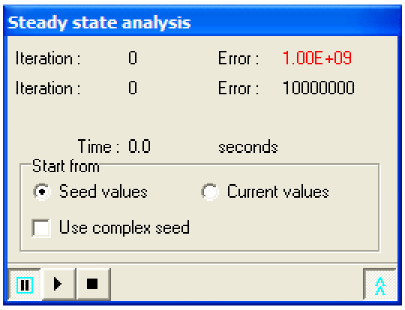
7.3 Adjusting DLS initial step size

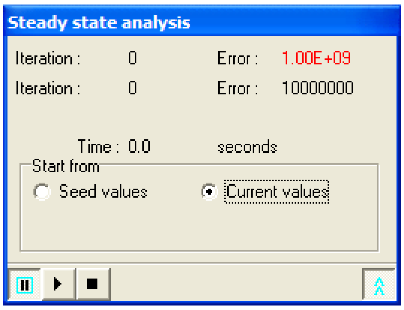
For systems with very high recycle flow rates (e.g. oxidation ditch systems) or systems with 'recycles-within-recycles', try adjusting one DLS solver setting as follows. From the **Project/Current Project Options/ Numerical parameters** menu, click on the **Options** button in the **Steady state solver method** section, and change the **Initial size** in the **Decoupled linear search** section to 1 (from the default value of 5).



7.4 Two-step steady-state solution

If it appears that the solver is encountering problems with pH calculations (e.g. pH values in units oscillate significantly from iteration to iteration), a two-step approach may resolve the problem. From the **Project/Current Project Options/ Model** menu (or by clicking on the **Model options** button), de-select (uncheck) the **Include pH calculations** option. Run the steady state solver, starting from **Seed values**. This should converge to a solution (with pH 7 in all units). Return to the **Model options** and select (check) the **Include pH calculations** option. Re-run the steady state solver, but start from **Current values**.





8 ASH CONTENT OF BIOMASS

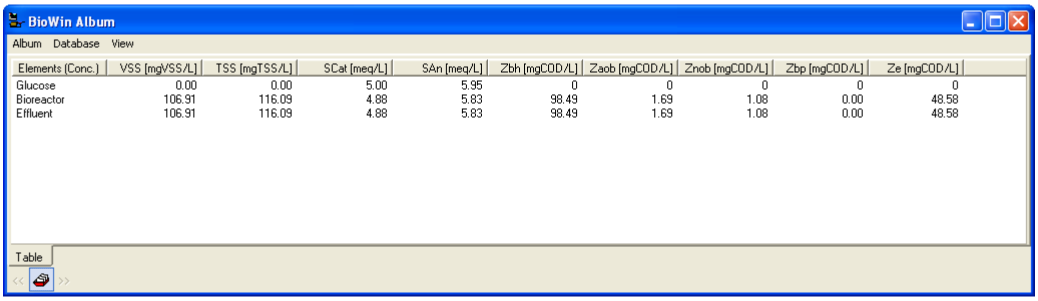
In systems with synthetic wastewater influents such as glucose the MLSS typically is slightly higher than the MLVSS even though the influent contains no ISS. Presumably this is due to the inclusion of some dissolved inorganic salts within the organism in the growth process. To account for this situation, BioWin now allows an ash content for biomass (and endogenous residue) to be specified via the **Project / Parameters / Other / General** tab.

Note: When loading 'old' BioWin files, the value for ash content is set at zero. When new configurations are started the value is set to the default of 8%.

Consider the system shown below. Run a steady state simulation and open the Album (see below). The difference between TSS and VSS is 9.18 mg/L. There is no influent ISS, so this difference must be accounted for as synthesis ISS. The sum of the biomass components [heterotrophs, autotrophs (AOBs and NOBs) and endogenous residue in this case] is: 98.49 + 1.69 + 1.08 + 48.58 = 149.84 mgCOD/L. All these components have COD/VSS ratios of 1.42, so the corresponding VSS contribution from biomass is 149.84/1.42 = 105.52 mgVSS/L. In this case the synthesis ash content was specified as 8%; that is, if X is the ash content in mg/L:

$$\frac{X}{105.52 + X} = 0.08$$

Solving: X = 9.18 mg/L



Elements (Conc.)	VSS [mgVSS/L]	TSS [mgTSS/L]	SCat [meq/L]	SAn [meq/L]	Zbh [mgCOD/L]	Zaob [mgCOD/L]	Znob [mgCOD/L]	Zbp [mgCOD/L]	Ze [mgCOD/L]
Glucose	0.00	0.00	5.00	5.95	0	0	0	0	0
Bioreactor	106.91	116.09	4.88	5.83	98.49	1.69	1.08	0.00	48.58
Effluent	106.91	116.09	4.88	5.83	98.49	1.69	1.08	0.00	48.58

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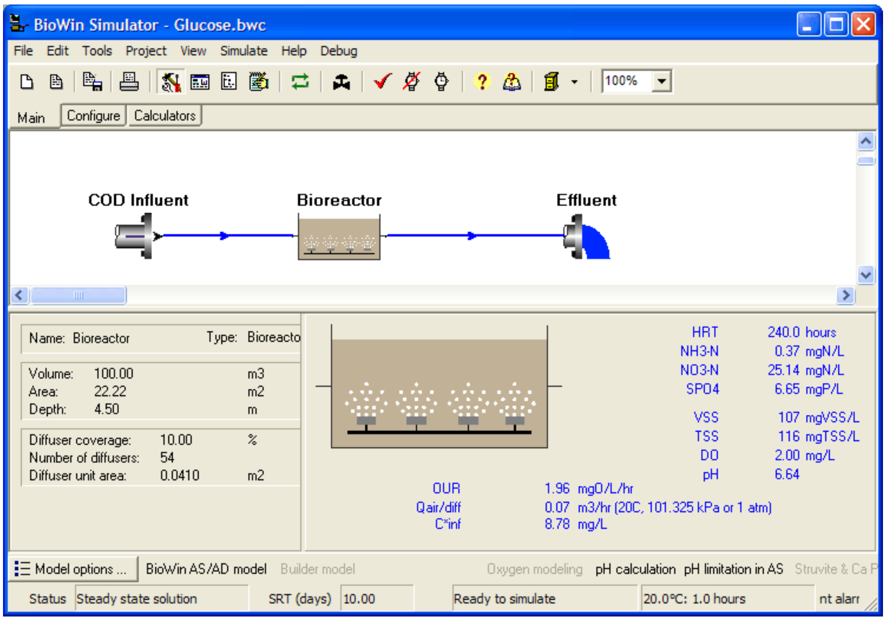


FIGURE 3. *EXAMPLE DEMONSTRATING ASH CONTENT OF BIOMASS.*

Appendix 3. Introduction on modelling

2019/2021-UWS/SE/08

Modelling of wastewater treatment processes and plants

BioWin Case Study Wastewater Treatment Modeling

Sebastiaan (Bas) Meijer Ph.D. meijer@asmdesign.nl

➢Developments of Wastewater Treatment

< 1970

Goal: Urban Hygiene and Sanitation

Method: primary treatment; grit and sand removal and (enhanced) primary settling

1970-1990

Goal: Nature protection; removing organic carbon (BOD) and ammonium

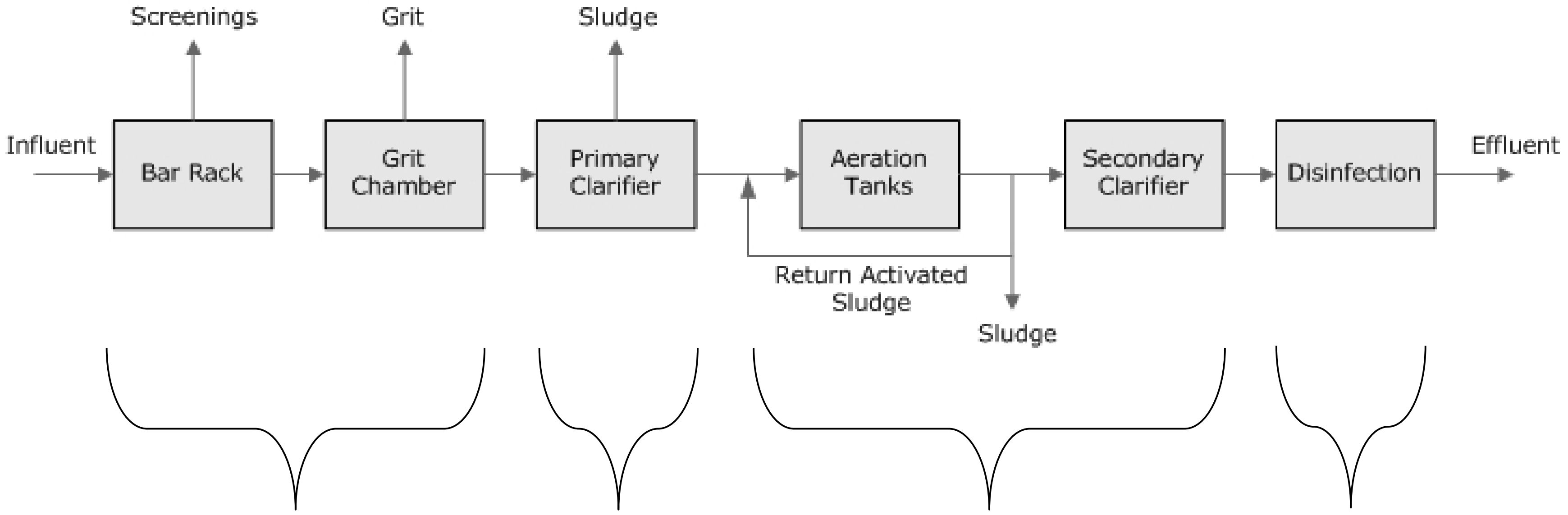
Method: secondary treatment; low SRT activated sludge including nitrification

>1990

Goal: Ecosystem protection; removing nutrients, micro pollutants and metals

Method: tertiary treatment; high SRT activated sludge including N and P removal

➢Standard Components of WWTP system



Preliminary treatment

Primary treatment

Secondary treatment

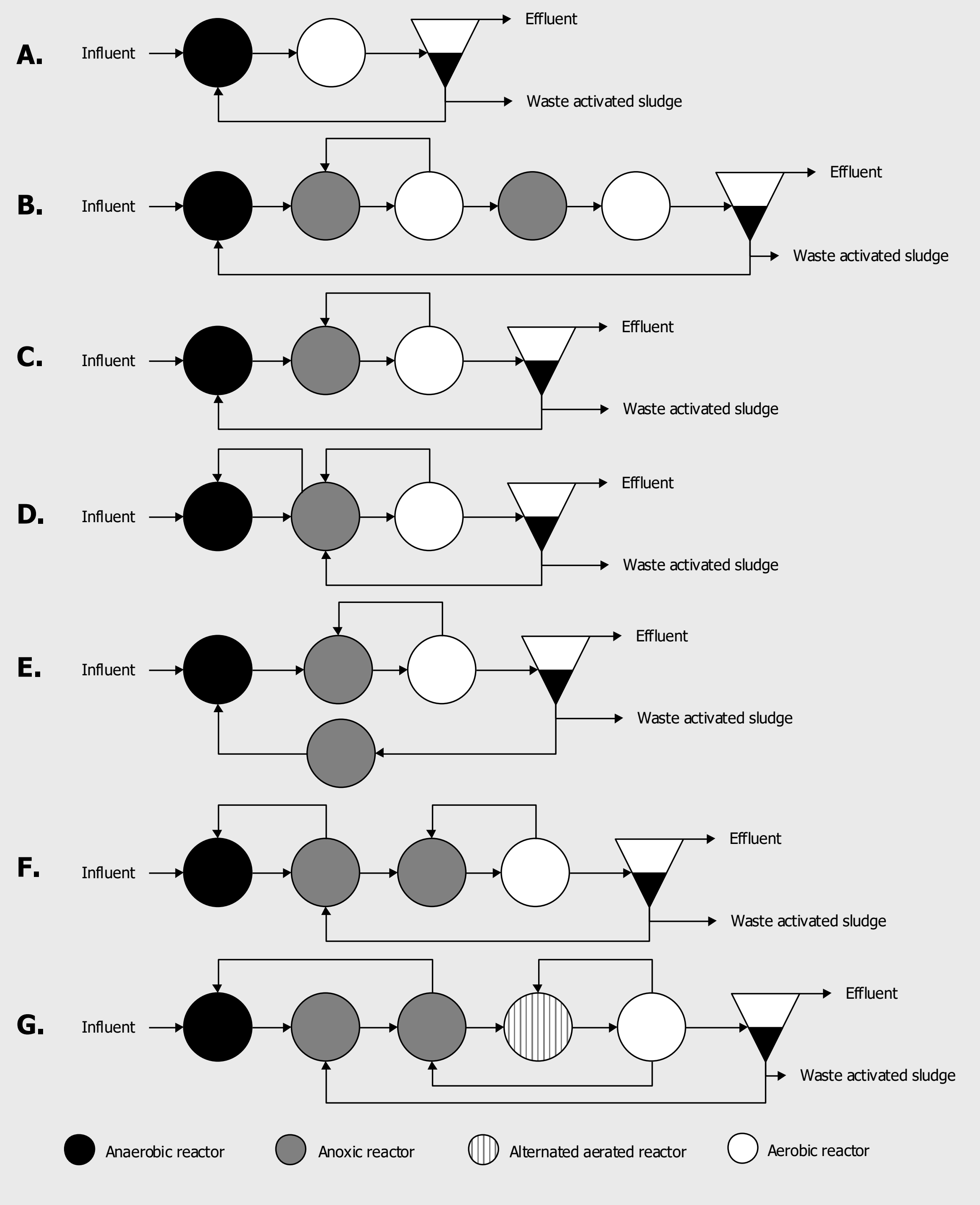
Final treatment

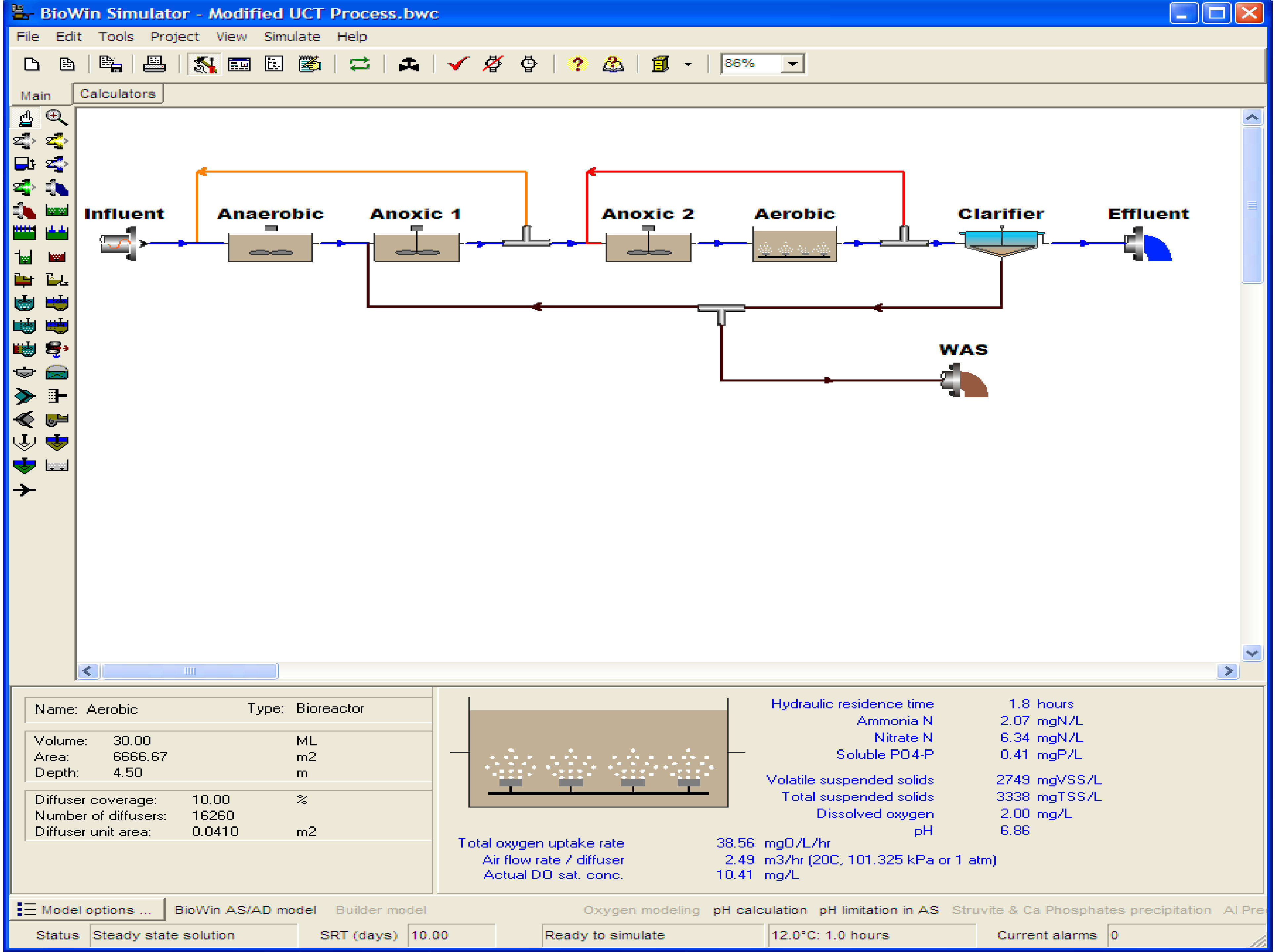
Tertiary treatment

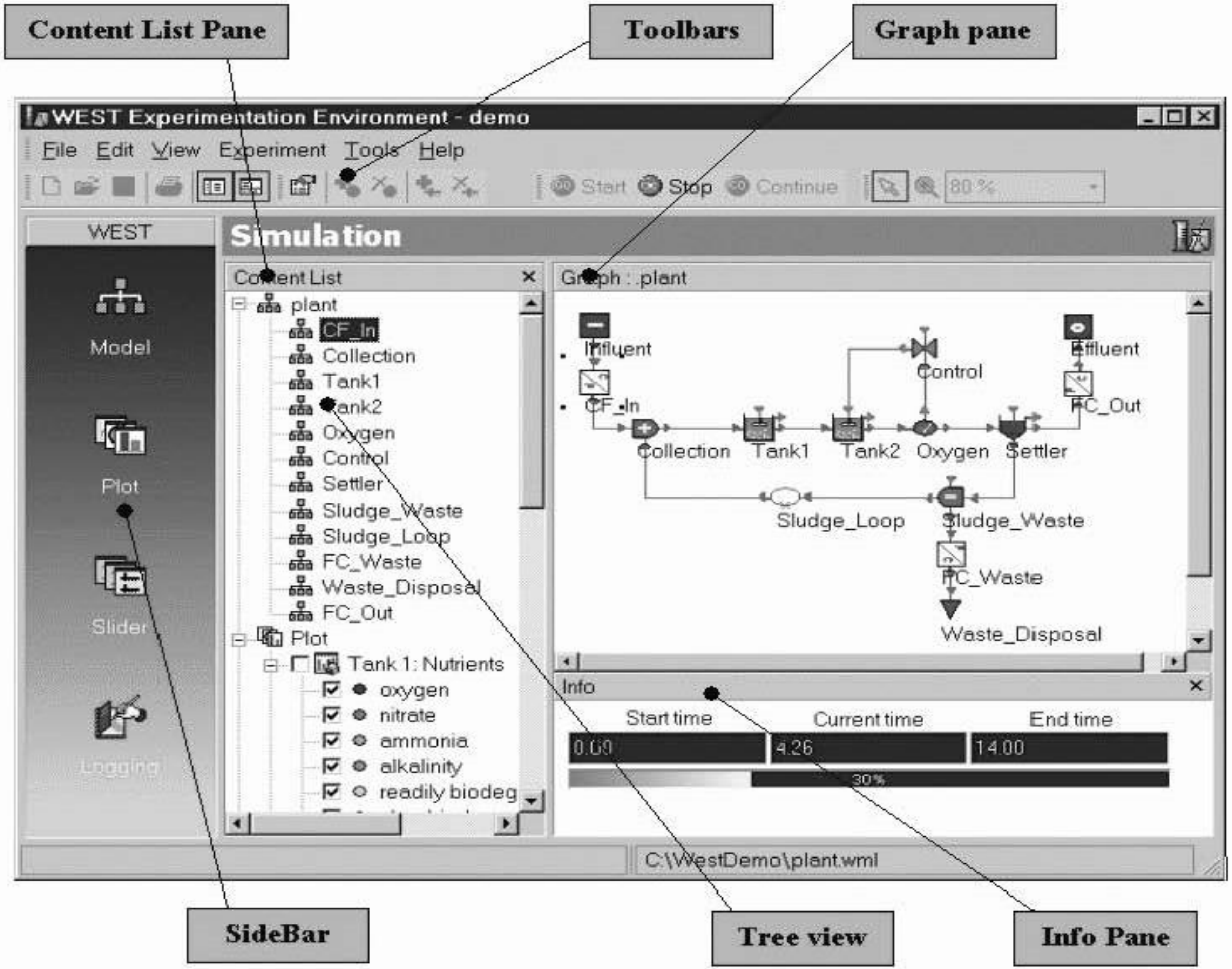
➢Tertiary design options

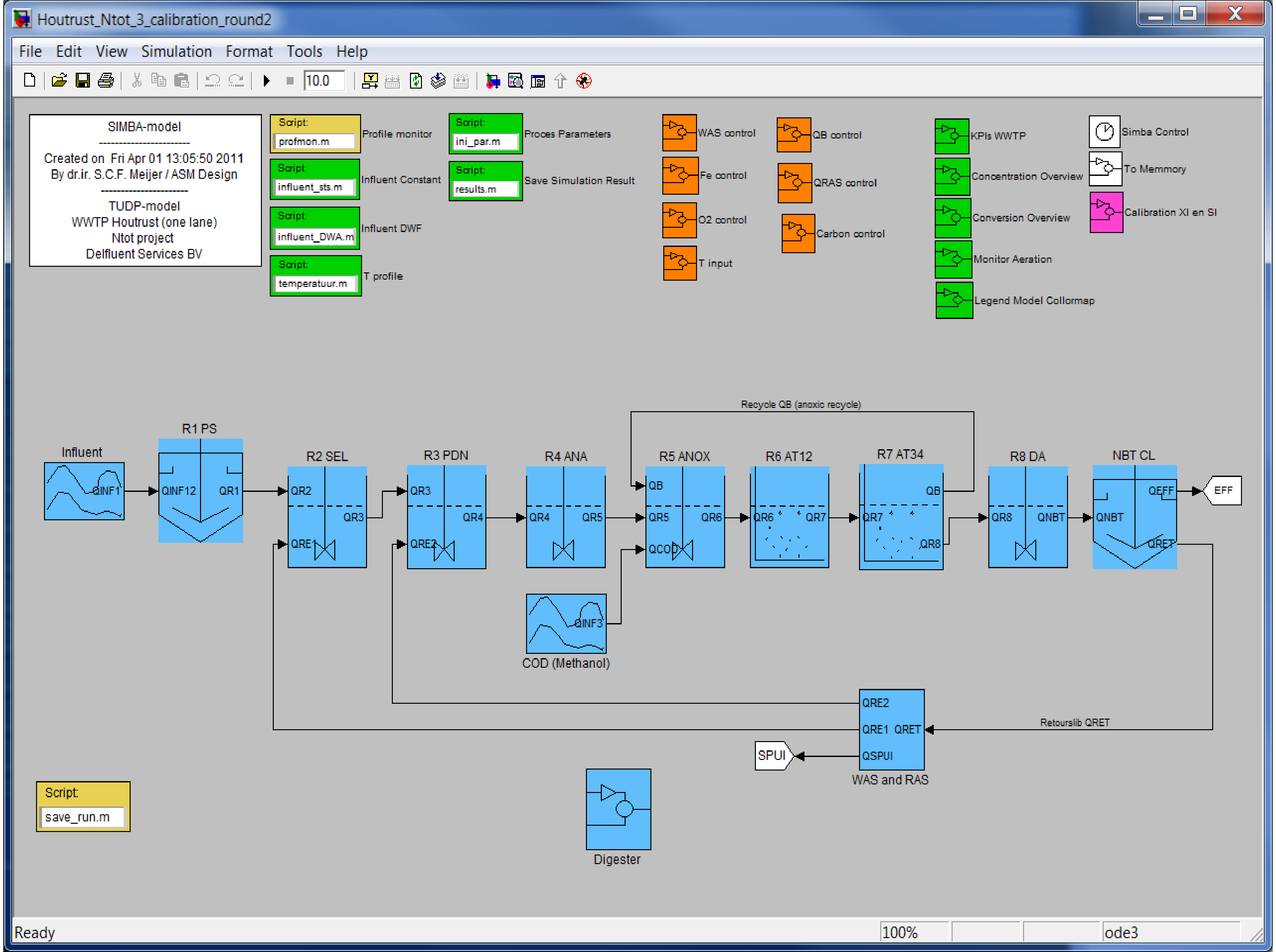
How to upgrade?

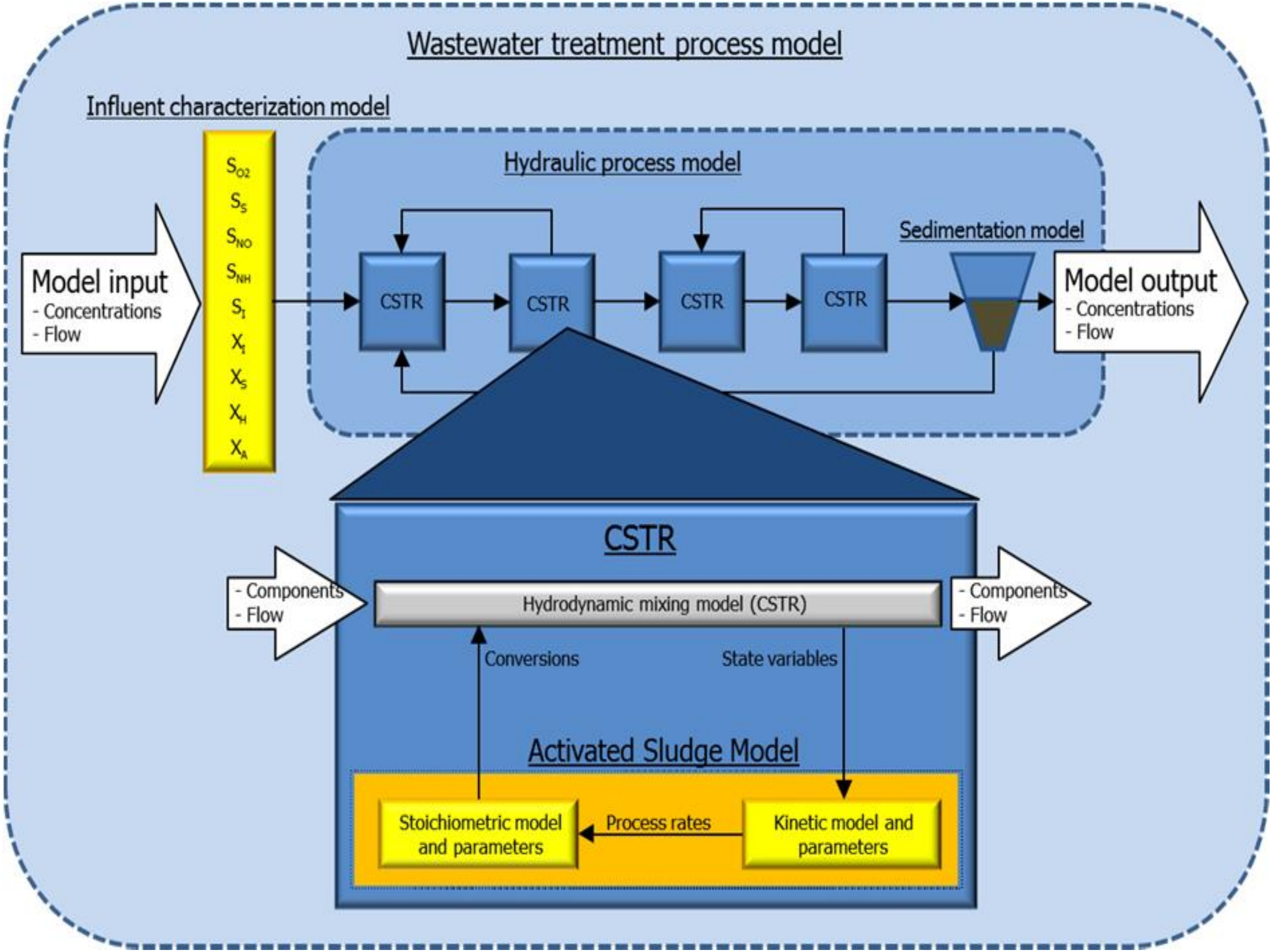
Use Model design tools…




BioWin Simulator - Modified UCT Process.bwc
File Edit Tools Project View Simulate Help
86%
Main
Calculators
Influent
Anaerobic
Anoxic 1
Anoxic 2
Aerobic
Clarifier
Effluent
WAS
Name: Aerobic
Type: Bioreactor
Volume: 30.00 ML
Area: 6666.67 m2
Depth: 4.50 m
Diffuser coverage: 10.00 %
Number of diffusers: 16260
Diffuser unit area: 0.0410 m2
Hydraulic residence time 1.8 hours
Ammonia N 2.07 mgN/L
Nitrate N 6.34 mgN/L
Soluble PO4-P 0.41 mgP/L
Volatile suspended solids 2749 mgVSS/L
Total suspended solids 3338 mgTSS/L
Dissolved oxygen 2.00 mg/L
pH 6.86
Total oxygen uptake rate 38.56 mgO/L/hr
Air flow rate / diffuser 2.49 m3/hr (20C, 101.325 kPa or 1 atm)
Actual DO sat. conc. 10.41 mg/L
Model options ...
BioWin AS/AD model
Builder model
Oxygen modeling
pH calculation
pH limitation in AS
Struvite & Ca Phosphates precipitation
Status
Steady state solution
SRT (days)
10.00
Ready to simulate
12.0°C: 1.0 hours
Current alarms
0


Content List Pane
Toolbars
Graph pane
WEST Experimentation Environment - demo
File Edit View Experiment Tools Help
Start Stop Continue
80 %
WEST
Simulation
Model
Plot
Slider
Logging
Content List
plant
CF_In
Collection
Tank1
Tank2
Oxygen
Control
Settler
Sludge_Waste
Sludge_Loop
FC_Waste
Waste_Disposal
FC_Out
Plot
Tank 1: Nutrients
oxygen
nitrate
ammonia
alkalinity
readily biodeg
Graph : .plant
Influent
Effluent
Control
CF_In
FC_Out
Collection
Tank1
Tank2
Oxygen
Settler
Sludge_Loop
Sludge_Waste
FC_Waste
Waste_Disposal
Info
Start time
Current time
End time
0.00
4.26
14.00
30%
C:\WestDemo\plant.wml
SideBar
Tree view
Info Pane


Houtrust_Ntot_3_calibration_round2
File Edit View Simulation Format Tools Help
SIMBA-model
Created on Fri Apr 01 13:05:50 2011
By dr.ir. S.C.F. Meijer / ASM Design
TUDP-model
WWTP Houtrust (one lane)
Ntot project
Delfluent Services BV
Script: profmon.m Profile monitor
Script: influent_sts.m Influent Constant
Script: influent_DWA.m Influent DWF
Script: temperatuur.m T profile
Script: ini_par.m Proces Parameters
Script: results.m Save Simulation Result
WAS control
Fe control
O2 control
T input
QB control
QRAS control
Carbon control
KPIs WWTP
Concentration Overview
Conversion Overview
Monitor Aeration
Legend Model Collormap
Simba Control
To Memmory
Calibration XI en SI
Recycle QB (anoxic recycle)
Influent
R1 PS
R2 SEL
R3 PDN
R4 ANA
R5 ANOX
R6 AT12
R7 AT34
R8 DA
NBT CL
EFF
COD (Methanol)
Retourslib QRET
SPUI
WAS and RAS
Digester
Script: save_run.m
Ready
100%
ode3

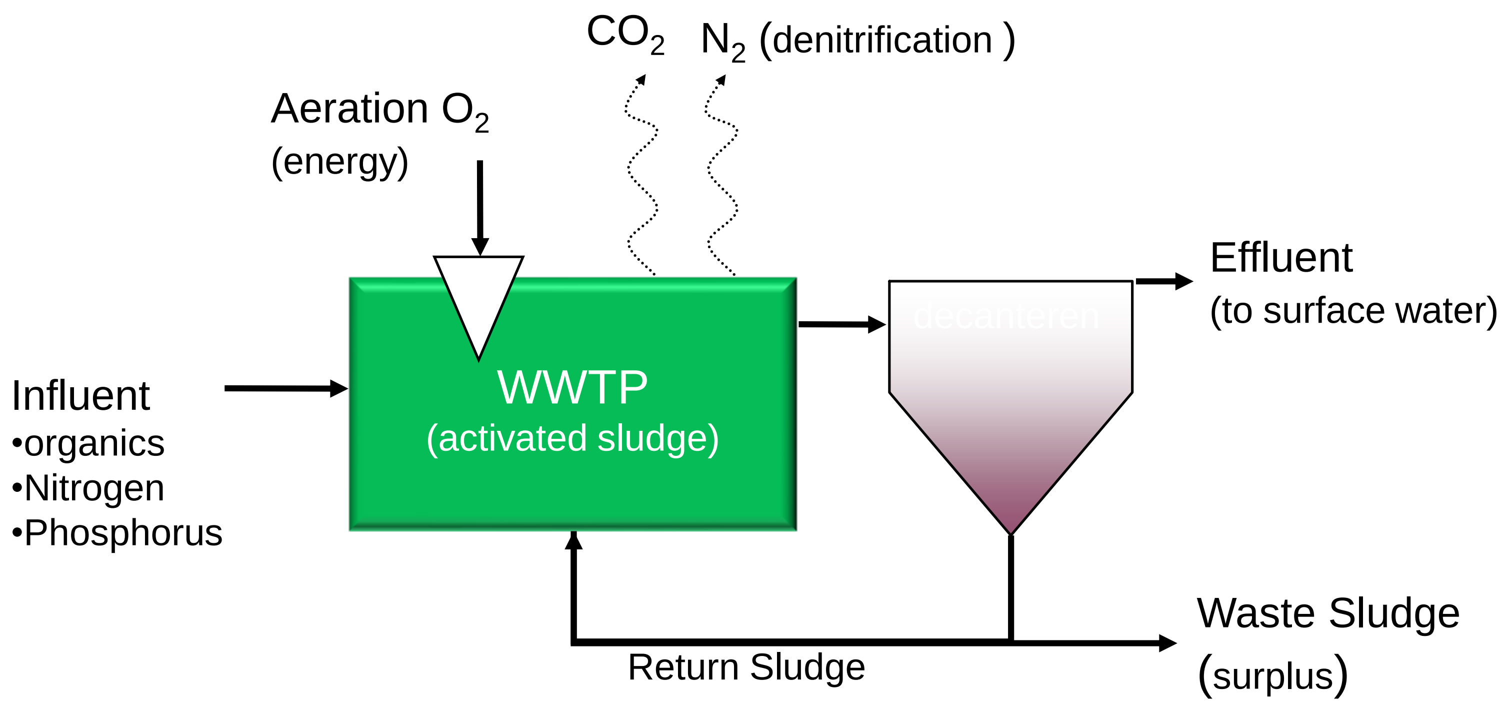


Wastewater treatment process model
Influent characterization model
Hydraulic process model
Sedimentation model
Model input
- Concentrations
- Flow
S_{O2}
S_S
S_{NO}
S_{NH}
S_I
X_I
X_S
X_H
X_A
CSTR
CSTR
CSTR
CSTR
Model output
- Concentrations
- Flow
CSTR
- Components
- Flow
Hydrodynamic mixing model (CSTR)
- Components
- Flow
Conversions
State variables
Activated Sludge Model
Stoichiometric model and parameters
Process rates
Kinetic model and parameters

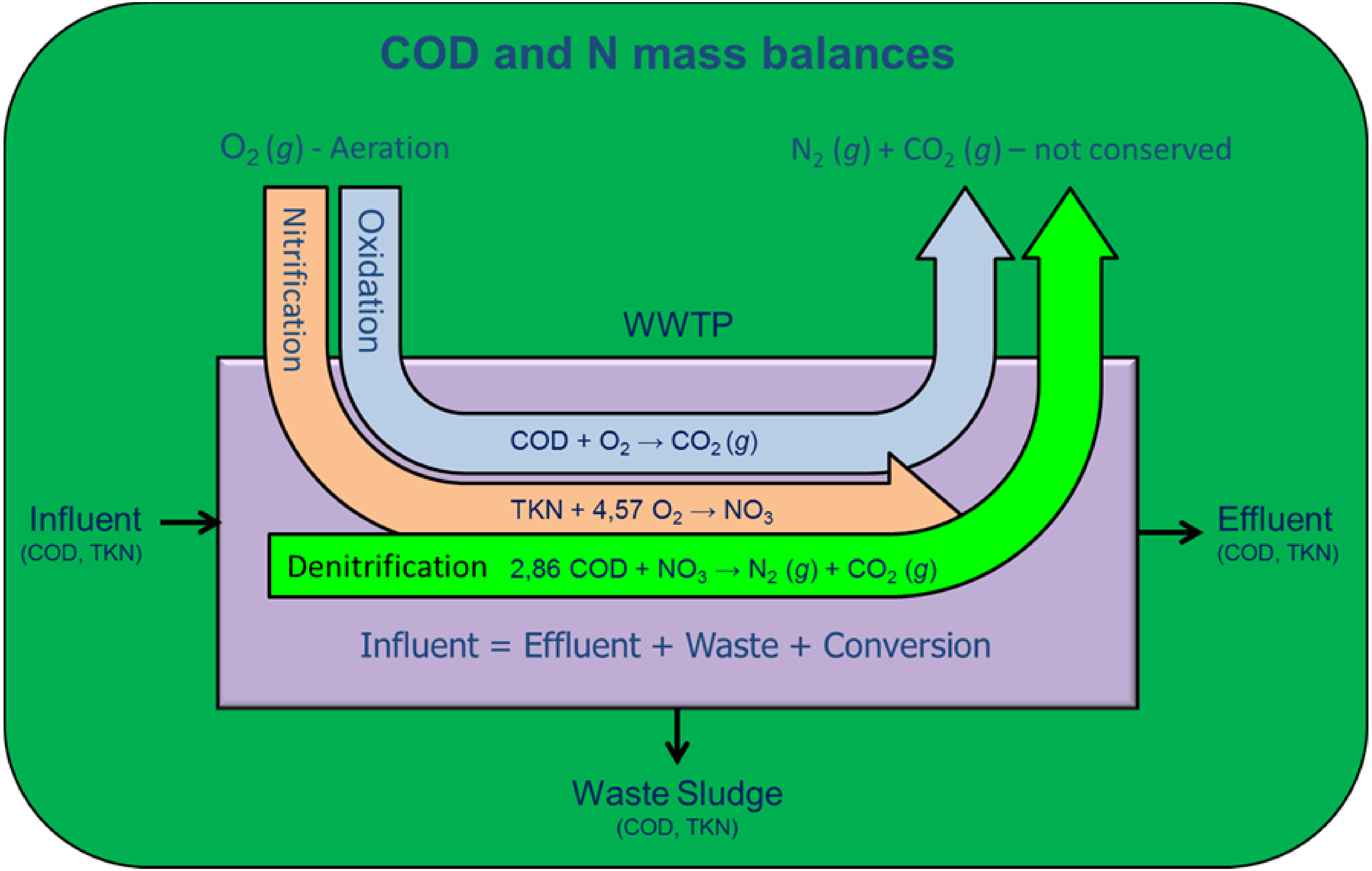
WWTP model: ensemble of sub-models

1. Plant (wide) model or process model
2. Mass flow model (process flow layout + tank reactors)
3. Sedimentation model (primary or secondary liquid/solid separation)
4. Influent characterization model
5. Hydraulic mixing model (e.g. CSTR, plug flow)
6. Activated sludge model (e.g. ASM1)
7. Kinetic model + Stoichiometric model

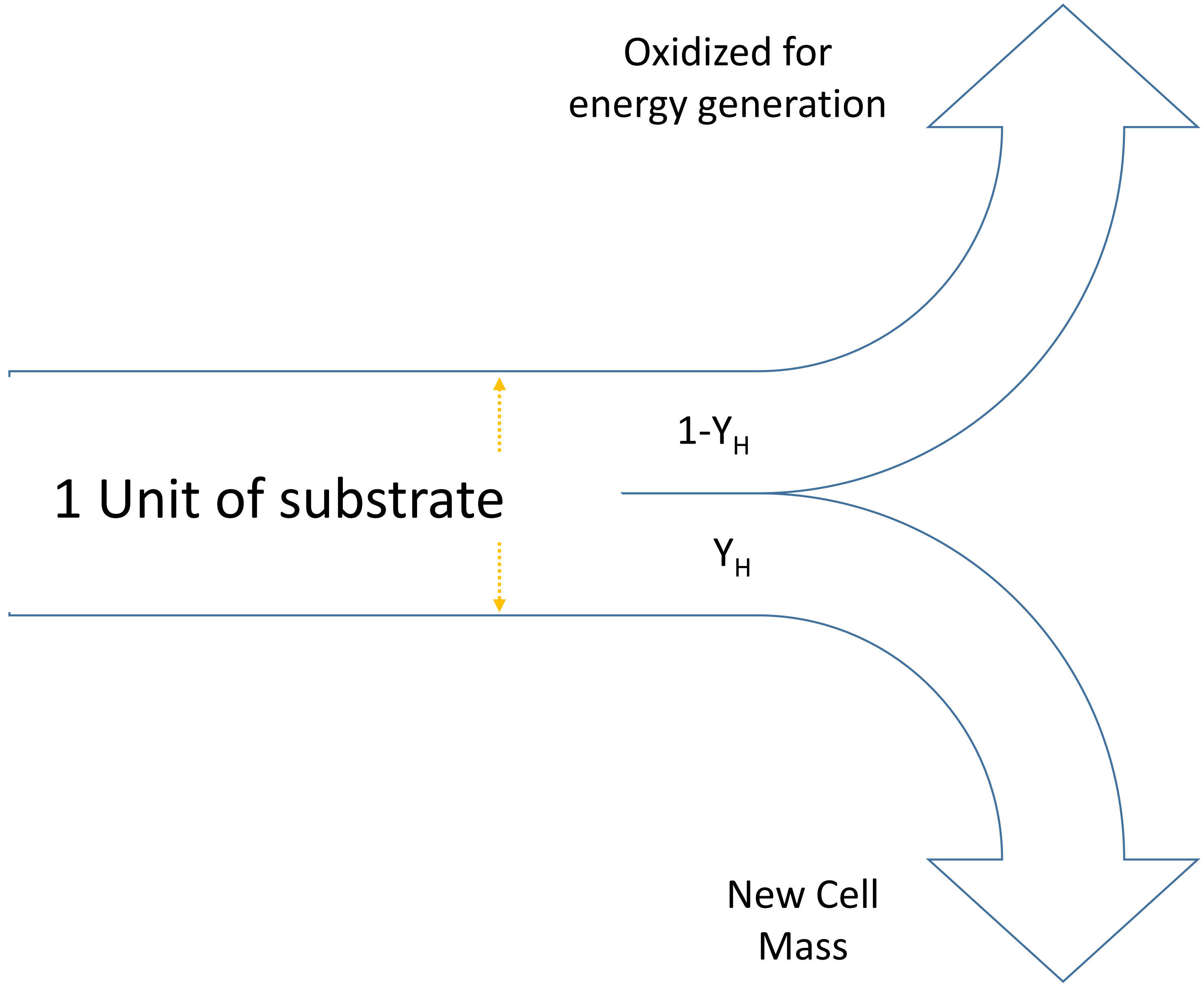
➢General principle of a wastewater treatment process



Organics + nitrogen + phophorus + oxygen $\rightarrow$ activated sludge + CO_2+ N_2



COD and N mass balances
O2 (g) - Aeration
N2 (g) + CO2 (g) – not conserved
Nitrification
Oxidation
WWTP
COD + O2 → CO2 (g)
TKN + 4,57 O2 → NO3
Denitrification
2,86 COD + NO3 → N2 (g) + CO2 (g)
Influent
(COD, TKN)
Effluent
(COD, TKN)
Influent = Effluent + Waste + Conversion
Waste Sludge
(COD, TKN)


Oxidized for
energy generation
1-Y_H
1 Unit of substrate
Y_H
New Cell
Mass

Theoretical Oxygen Demand of N-NO_3

From moles to grams!

Nitrification

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

$$M_{N-NH4} = 14 \frac{gN}{mole}$$

$$M_{oxygen} = 32 \frac{g\,O_2}{mole}$$

$$ThOD_{N-NH4} = \frac{2 \cdot 32}{14} = -4.57 \frac{g\,O_2}{gN-NH4}$$

Denitrification

$$2NO_3^- + 2H^+ \rightarrow N_2 + 2.5O_2 + H_2O$$

$$M_{N-NO3} = 14 \frac{gN}{mole}$$

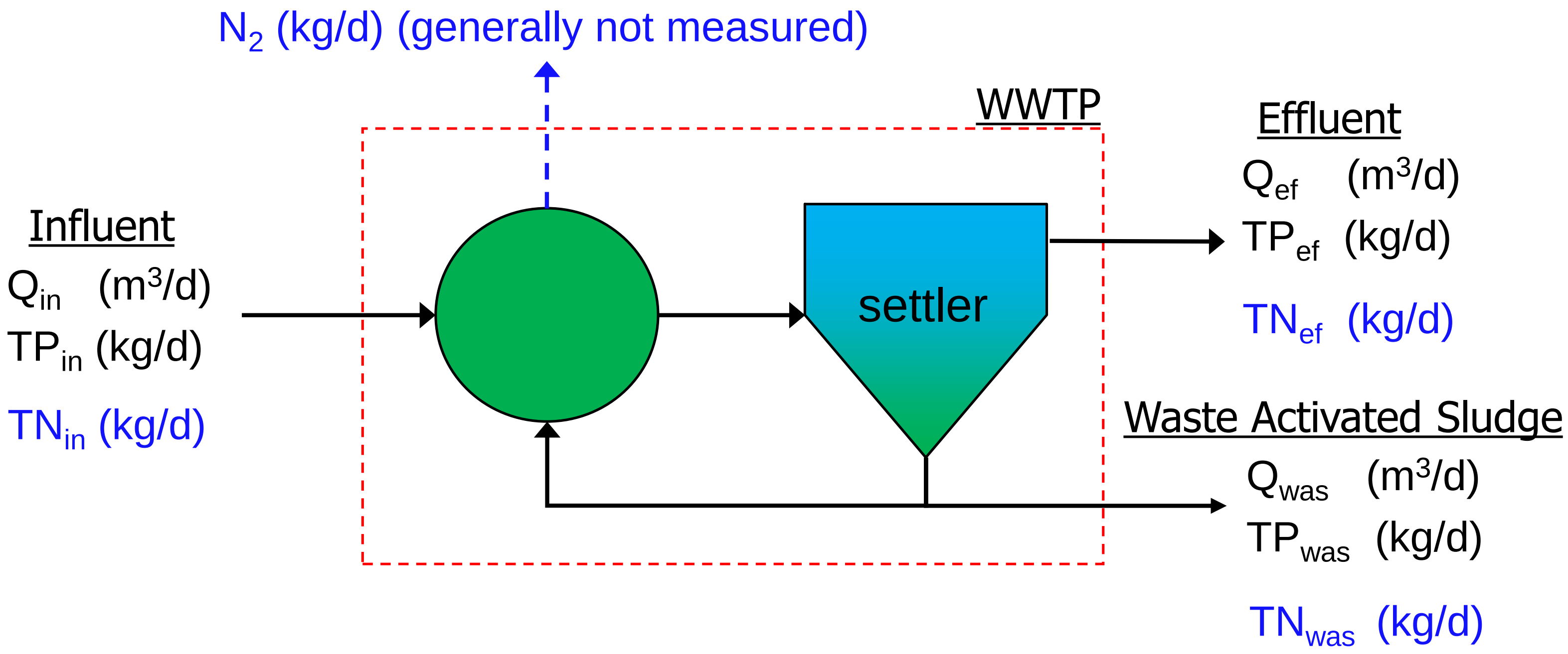
$$M_{oxygen} = 32 \frac{g\,O_2}{mole}$$

$$ThOD_{gN-NO3} = \frac{2.5 \cdot 32}{2 \cdot 14} = +2.86 \frac{g\,O_2}{gN-NO3}$$

$$NH_4^+ \rightarrow NO_3^- \rightarrow N_2 \;:\; -4.57 + 2.86 = -1.71 \frac{gO_2}{gN-N_2}$$

Mass balance for plant assessment

Conserved and non conserved compounds



Flow balance:

$$Q_{in} - Q_{ef} - Q_{was} = 0 \text{ (=conserved)}$$

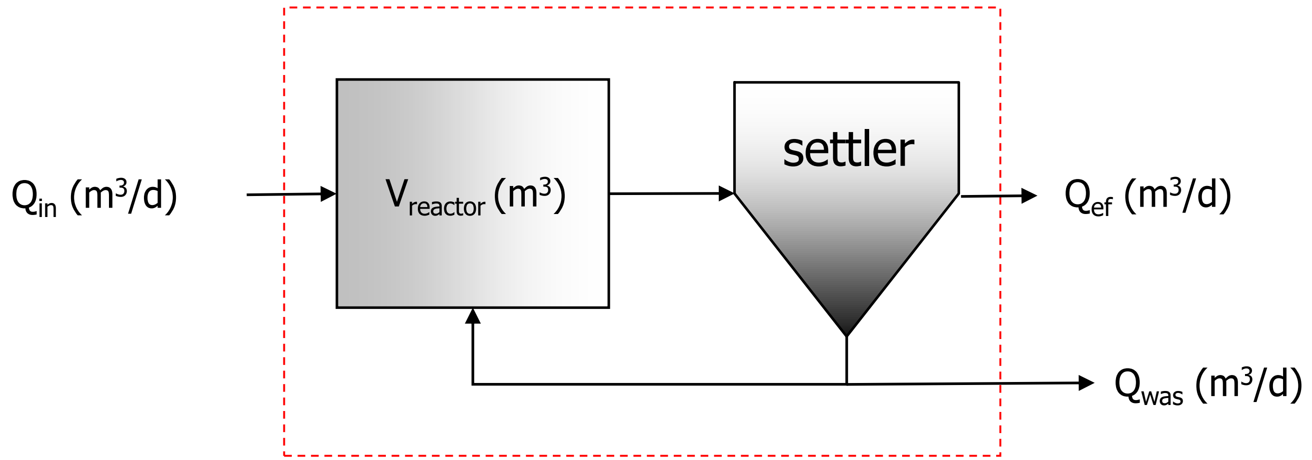
P balance:

$$TP_{in} - TP_{ef} - TP_{was} = 0 \text{ (=conserved)}$$

N balance:

$$N_{in} - N_{ef} - N_{was} = N_2 \text{ (denitrified load)} \neq 0$$

Hydraulic Residence Time (HRT)

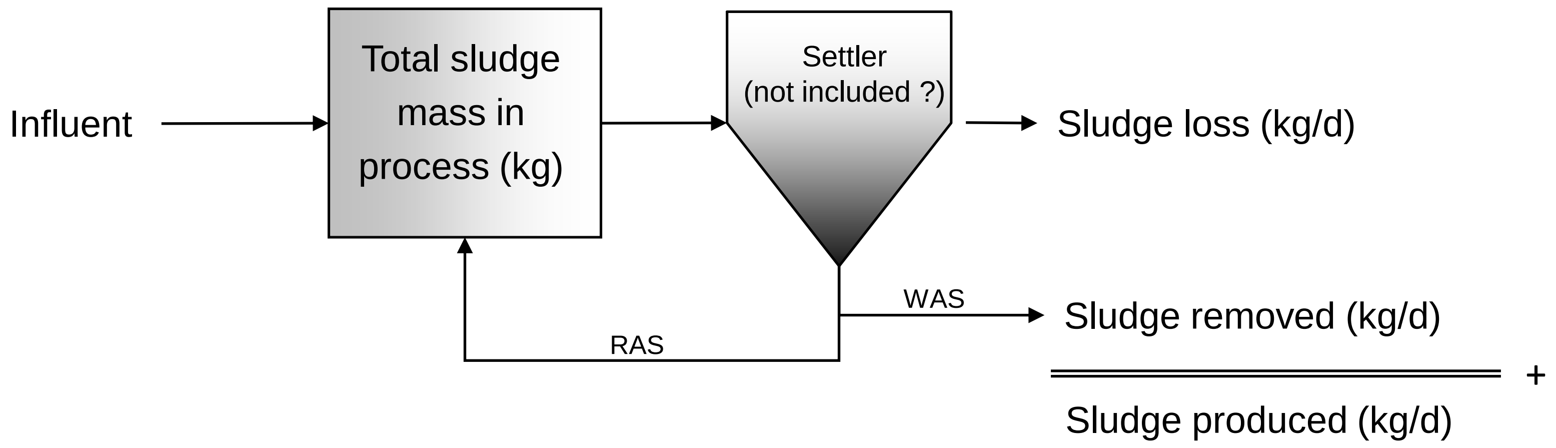


$$\text{Hydraulic Residence Time (d)} = \frac{\text{the total volume in the process } (m^3)}{\text{total flow passing per day } (m^3/d)}$$

Flow balance is conserved: $Q_{in} = Q_{ef} + Q_{was}$

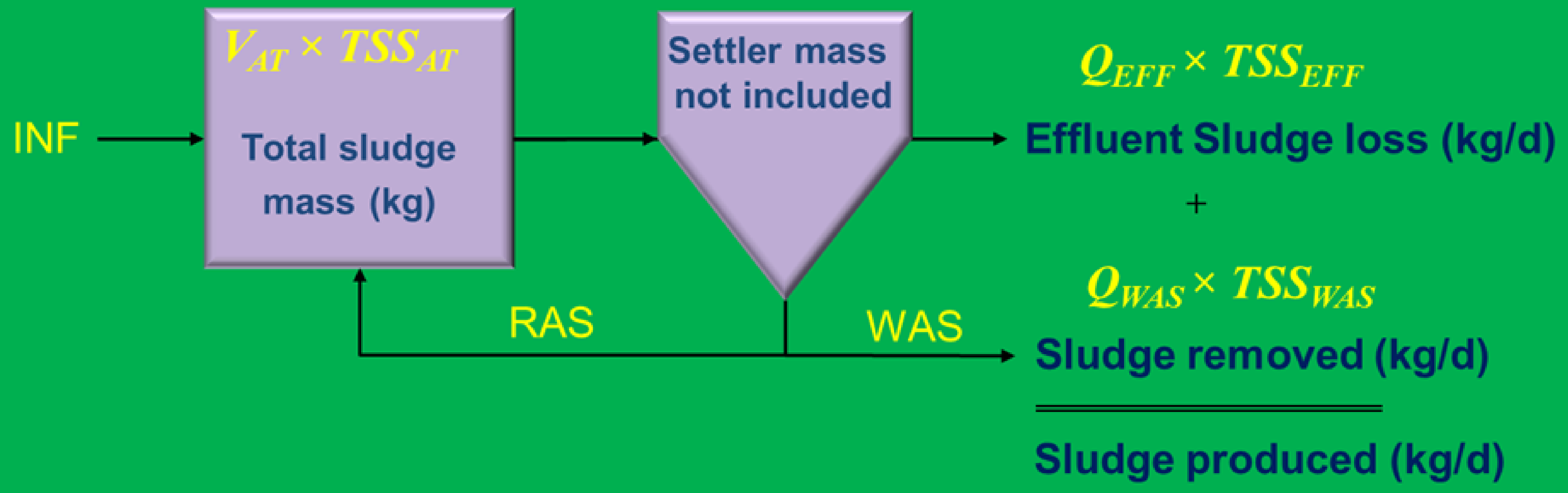
$HRT = V_{reactor} / (Q_{ef} + Q_{was})$ or $HRT = V_{reactor} / Q_{in}$ (d)

Sludge Retention Time (SRT)



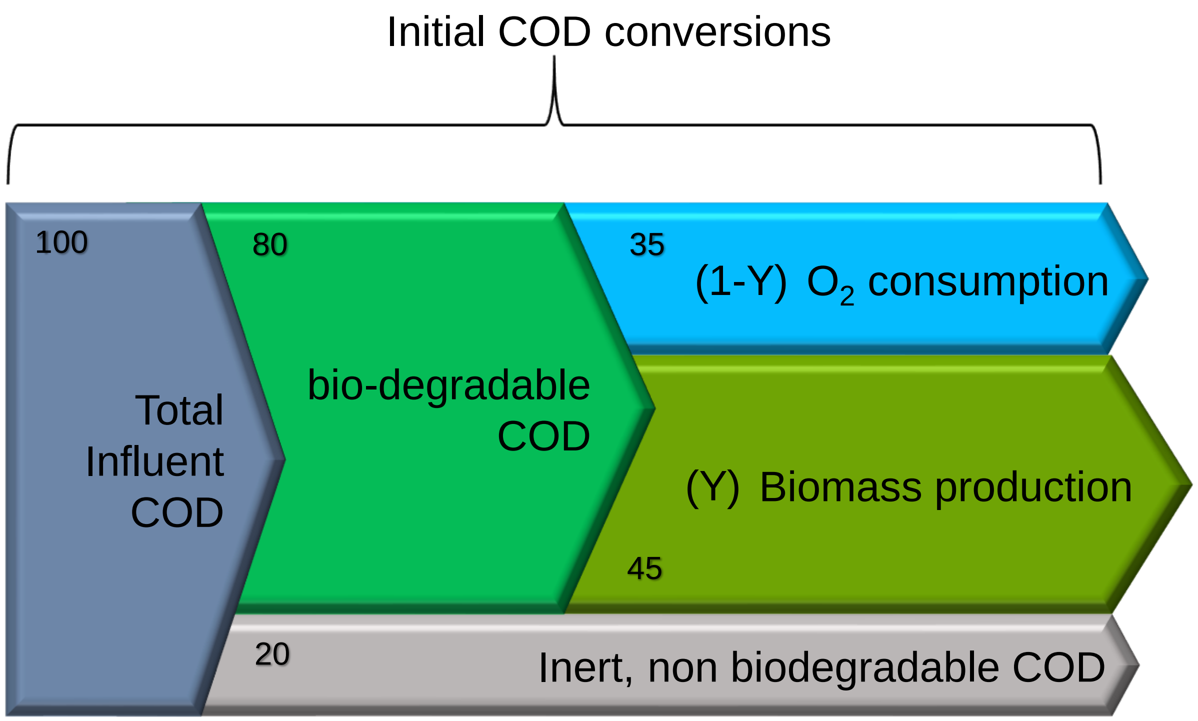
$$\text{Sludge Retention Time (days)} = \frac{\text{the total sludge mass in the process (kg)}}{\text{total sludge produced per day (kg/d)}}$$

Calculation of the Sludge Retention Time (SRT)



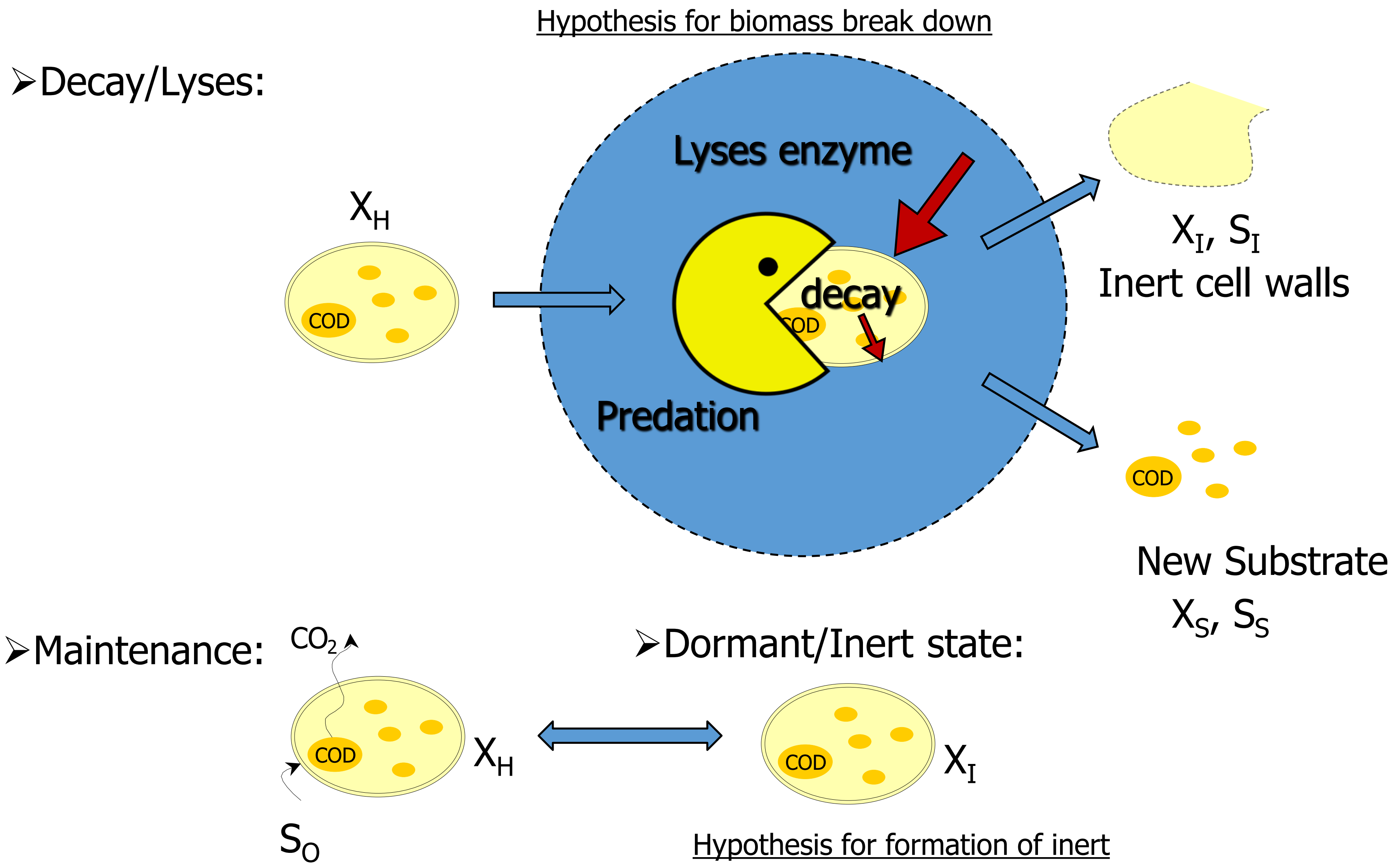
$$SRT = \frac{V_{AT} \times TSS_{AT}}{Q_{WAS} \times TSS_{WAS} + QE_{FF} \times TSS_{EFF}}$$

➢COD conversions and Sludge production

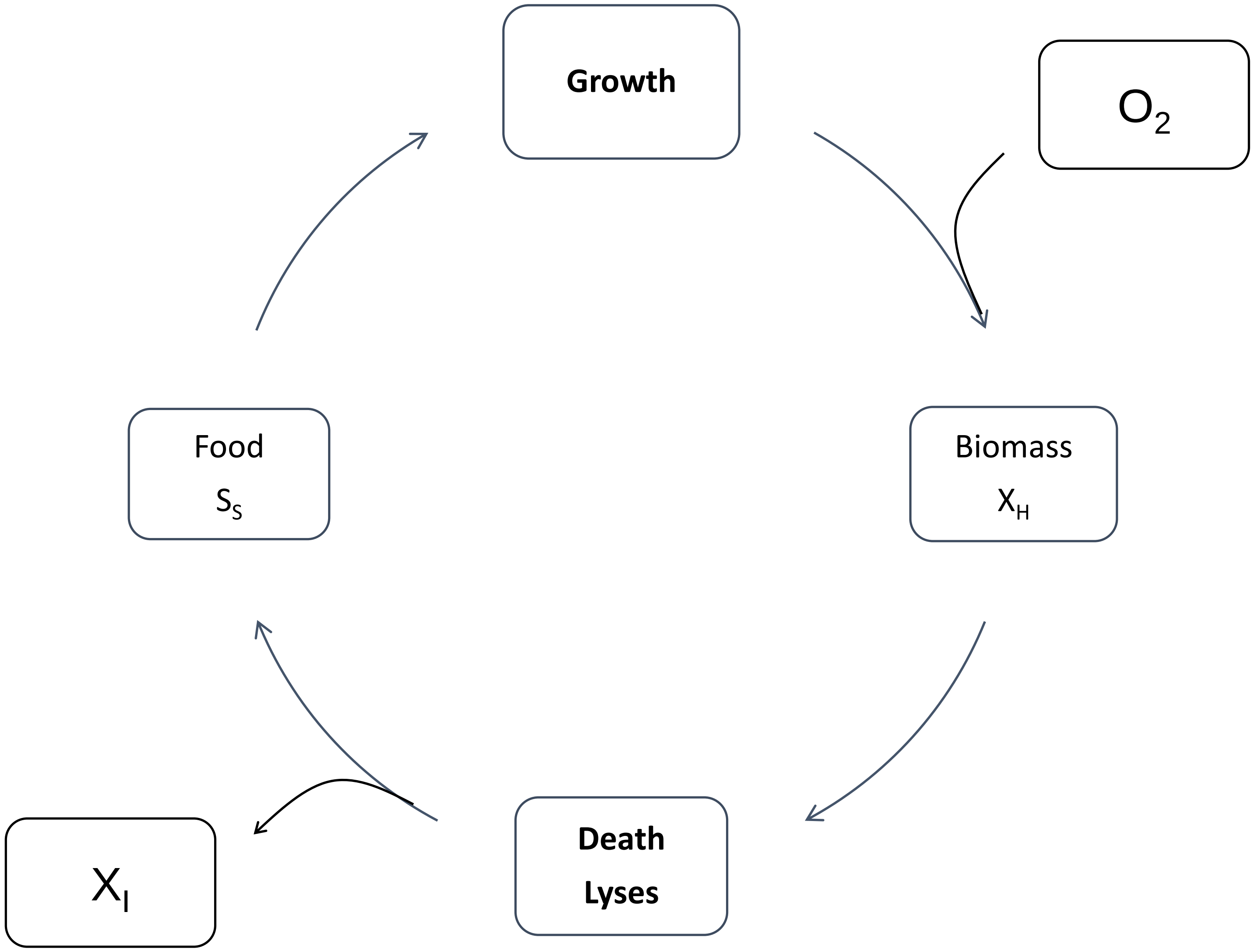


- Influent contains inert and bio-degradable COD
- Part of Bio-degradable COD becomes biomass (growth)
- Part of Bio-degradable COD is oxidized

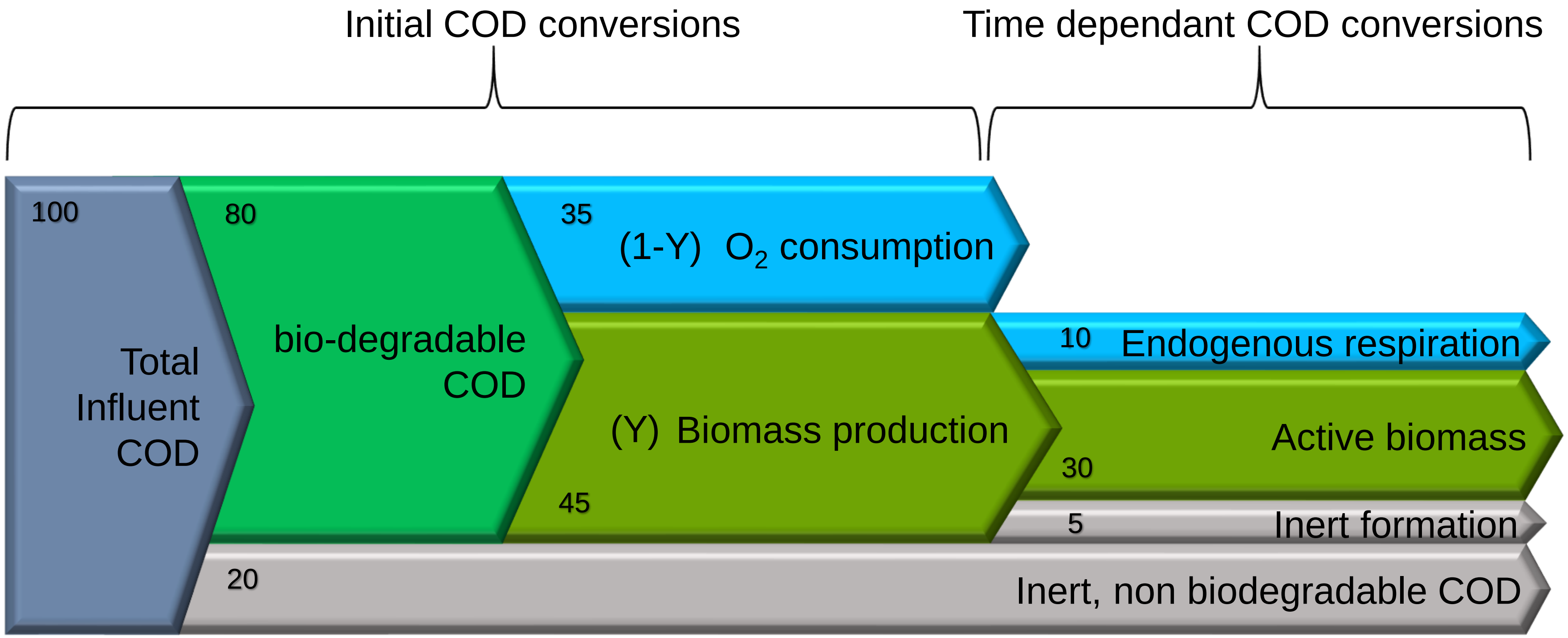
endogenous respiration and formation of inert material



biomass respiration cycle

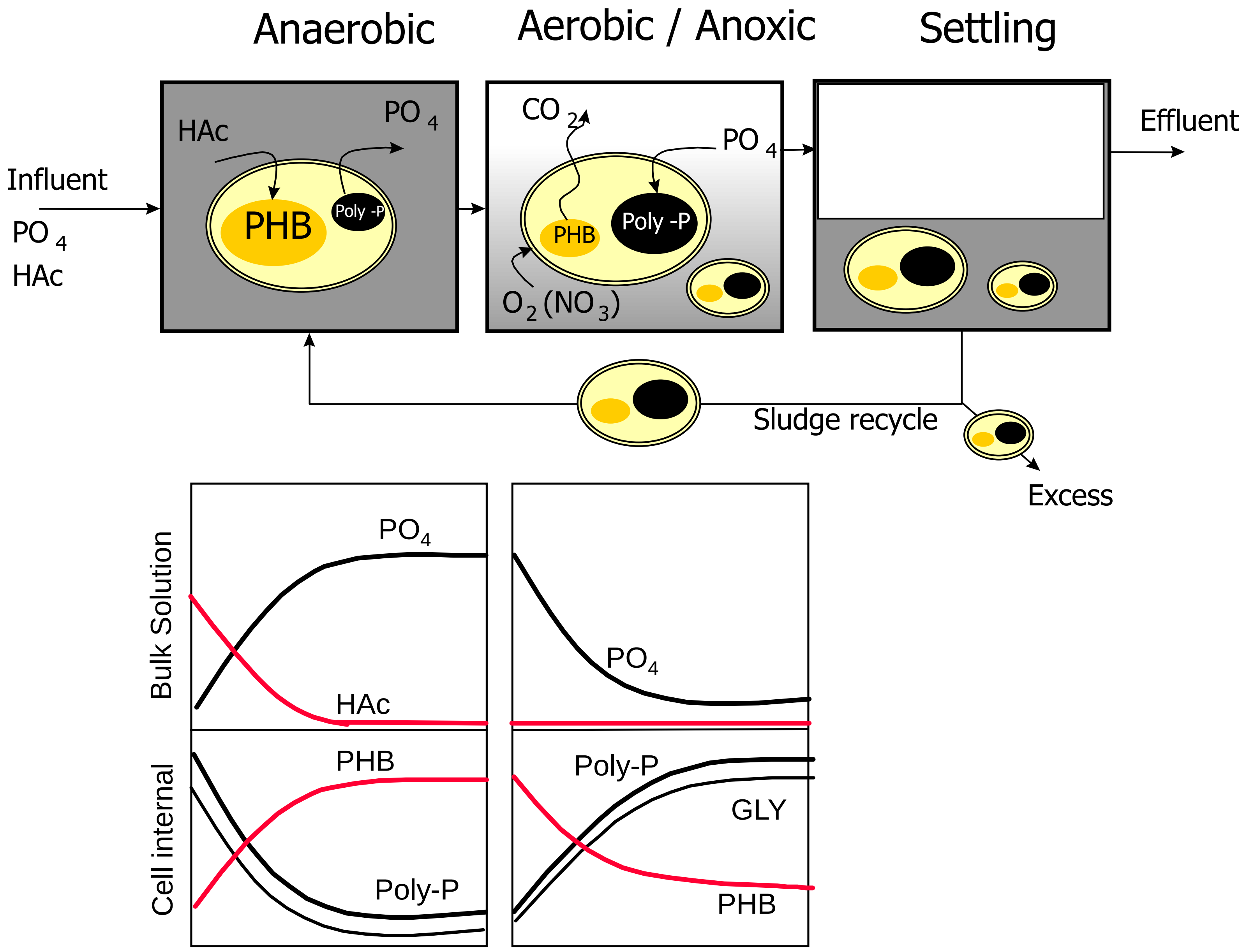


COD conversions and conservation

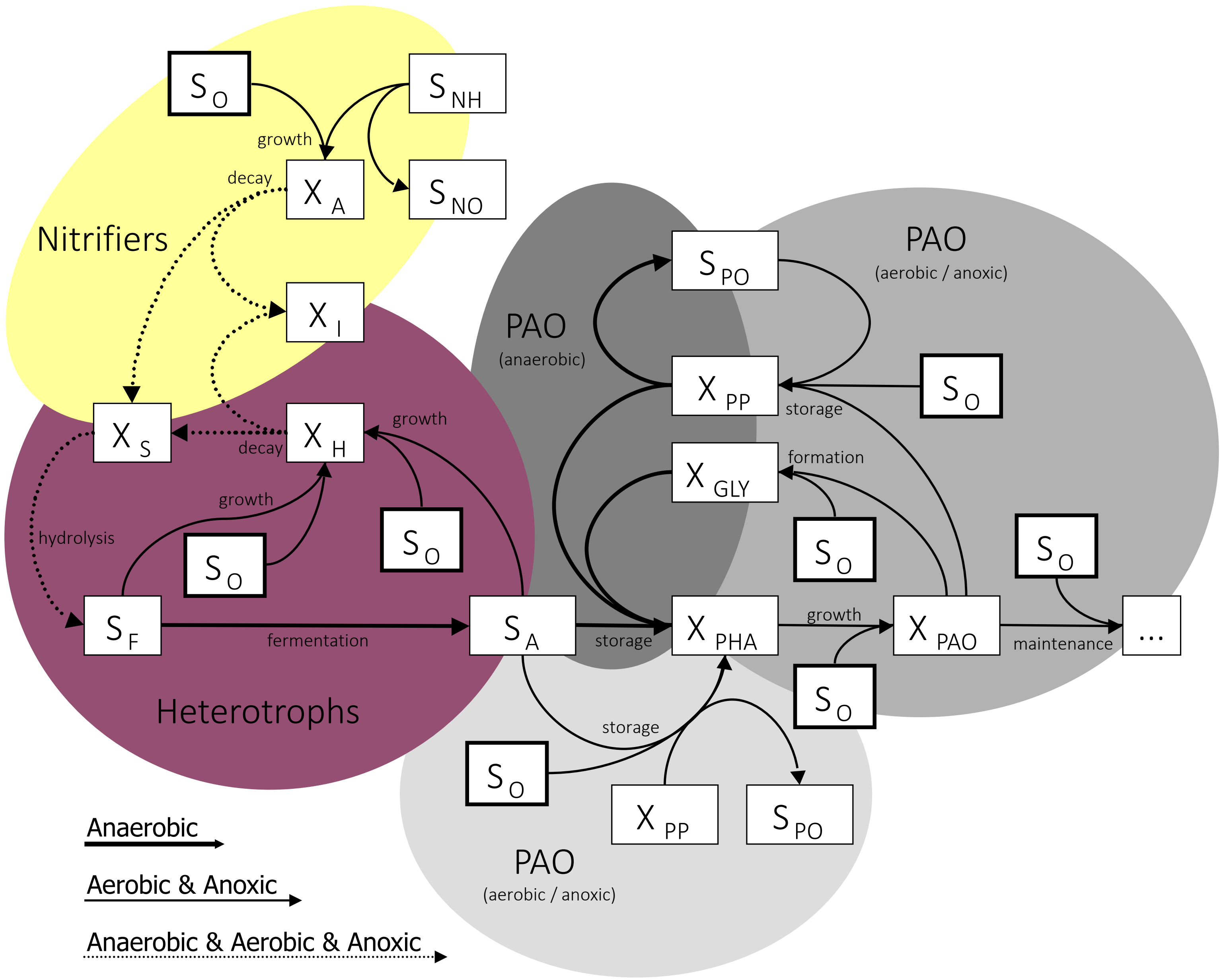


- With increasing time (SRT) less waste sludge (WAS) is produced
- but more oxygen consumption (= endogenous respiration)
- Two types of inert; formed in process and from influent
- Design of WWTP is essential; time = volume = waste sludge = aeration costs, etc.
- Use an ASM model…!

➢Fitting BioP in the model



➢Activated sludge model; Interrelated sets of bio-conversions



Data requirements for modelling

- Influent
  - ❑ Temperature
  - ❑ Flow
  - ❑ Loading and concentrations
- Effluent requirements
- **Selection for design**
  - ❑ Type of treatment process
  - ❑ Volumes
- Selection for operation
  - ❑ Sludge residence time (SRT)
- Design tool (software)

Municipal wastewater; characterization

Quantity:

- 90% of total sewage is faces and urine
- In average 1.5 L per person per day
- Tap water: 130 to 200 L per person per day
- Industrial Water: depending on local situation
- Rainwater: yearly average + 25% on Dry Weather Flow
- Infiltration: depending on sewer situation

Conclusion:

- Quantity and concentrations are largely depending on sewer system

Approach:

- Influent measurements (flow and concentrations)
- Influent characterization for model design (different fractions)

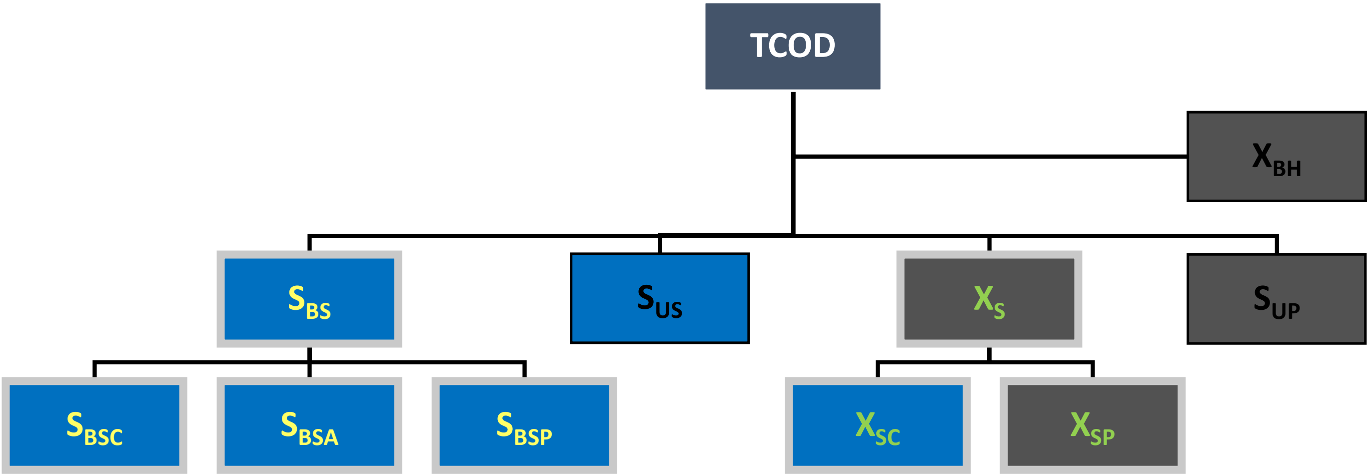
Typical Influent Quality (DWF)

- 24h flow variation
- Rain events

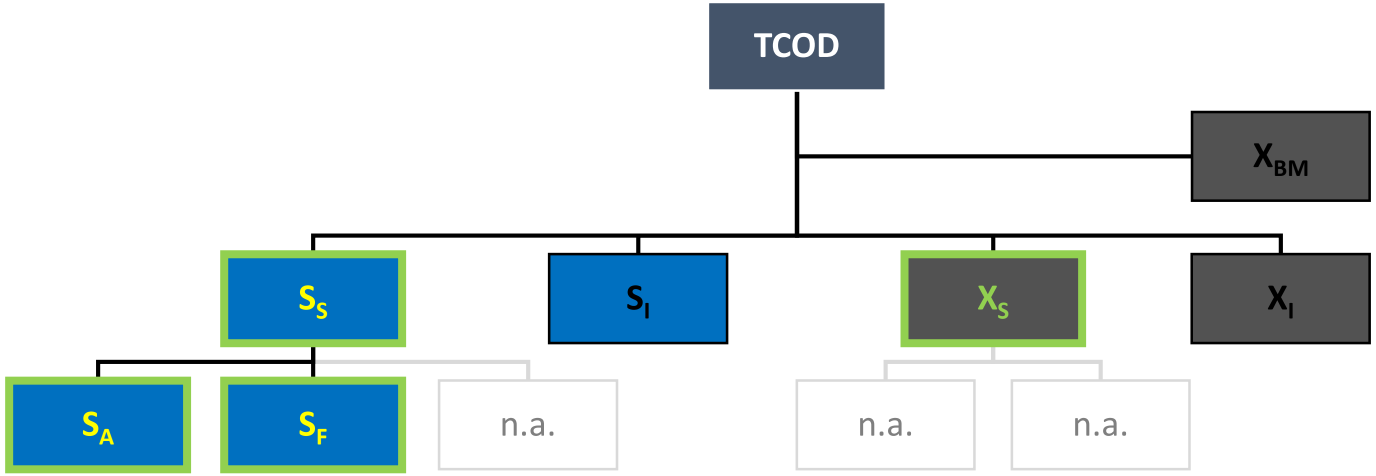
• COD	400 to 600	mg COD/L
• BOD	200 to 300	mg BOD/L
• TN	40 to 60	mg N/L
• TP	4 to 8	mg P/L
• TSS	200	mg/l

• Micro pollutants	µg/L

BioWin ASAD



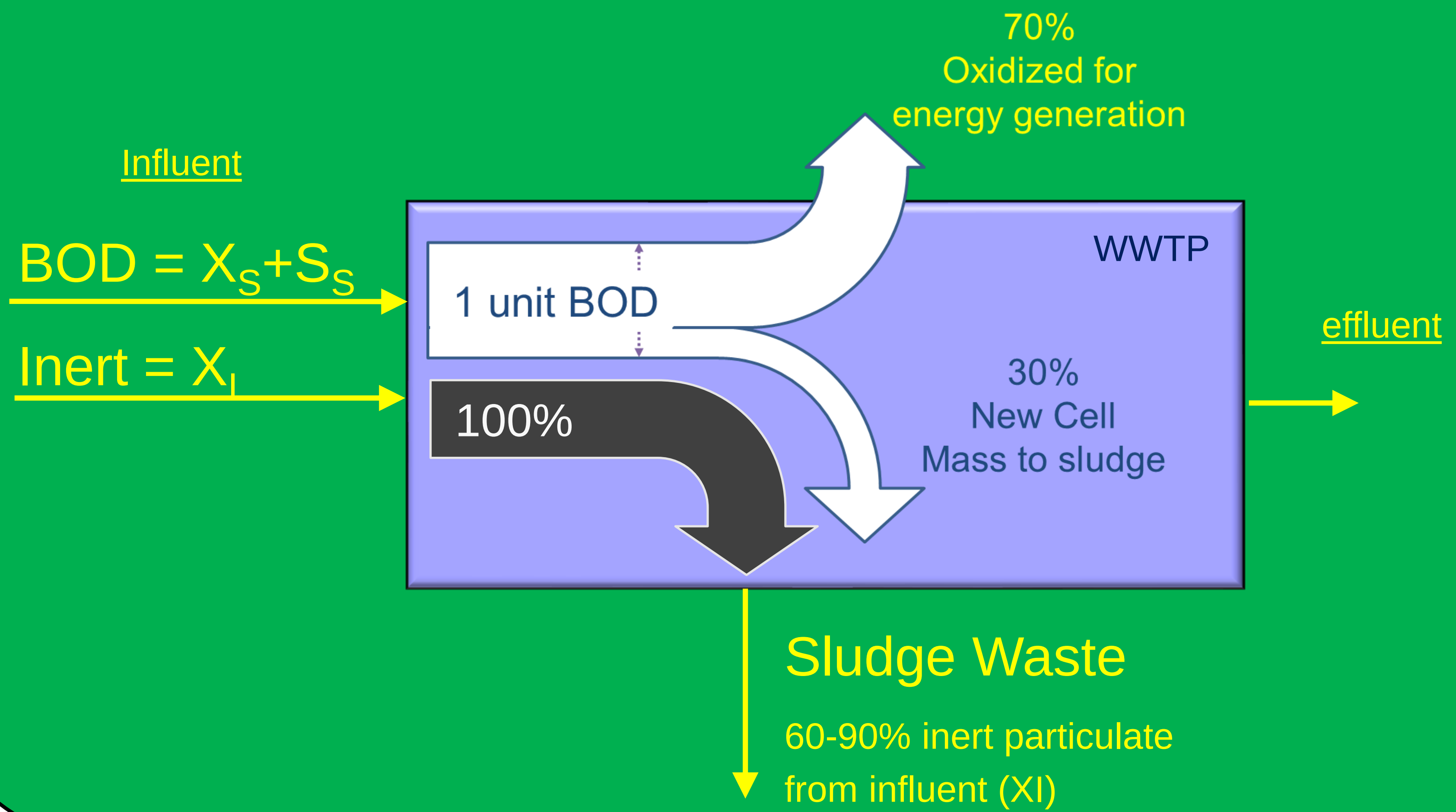
ASM2d



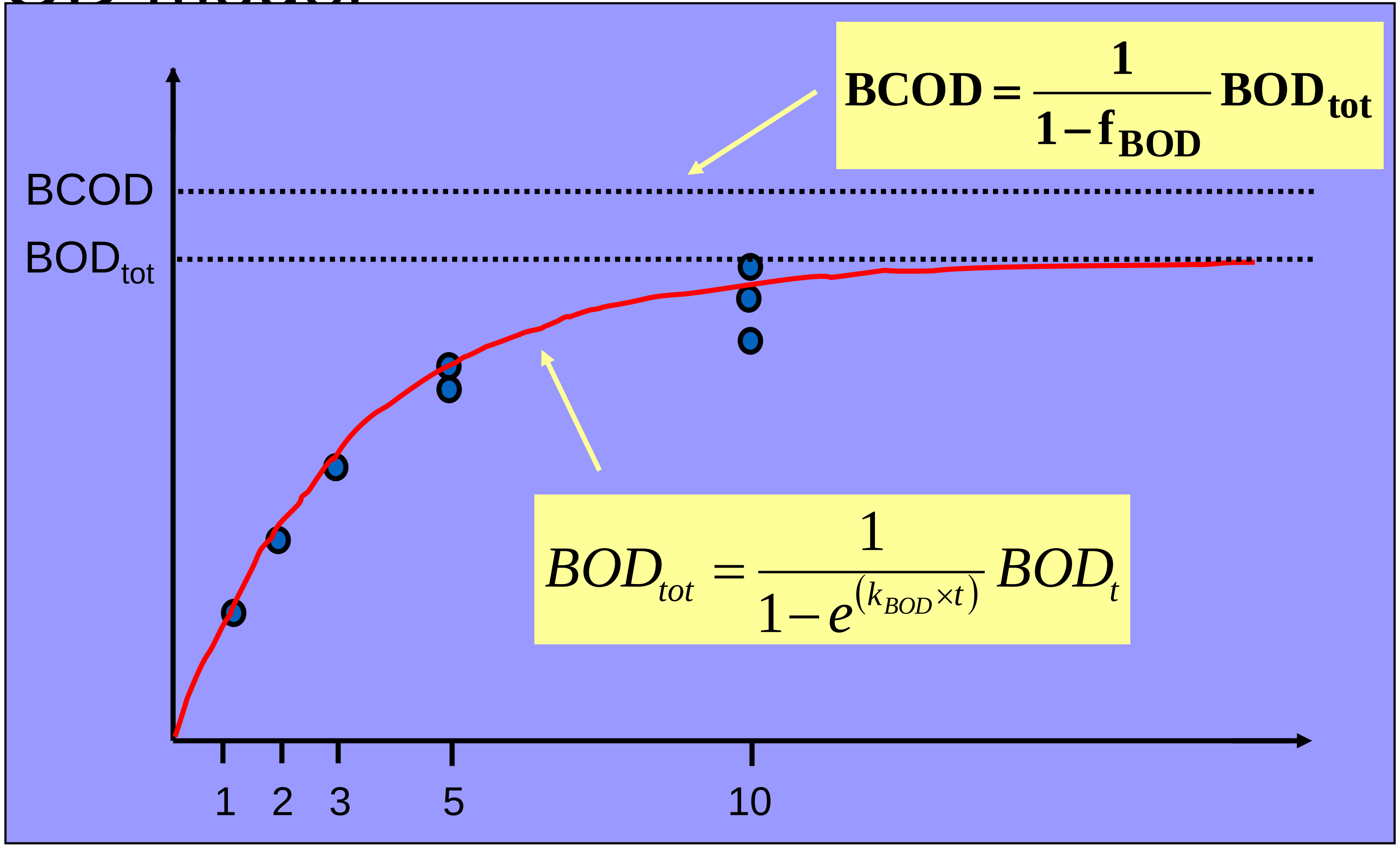
Inert particulate COD → Sludge production

measure sludge waste → in the model adjust X_I

no influent BOD tests needed in practice



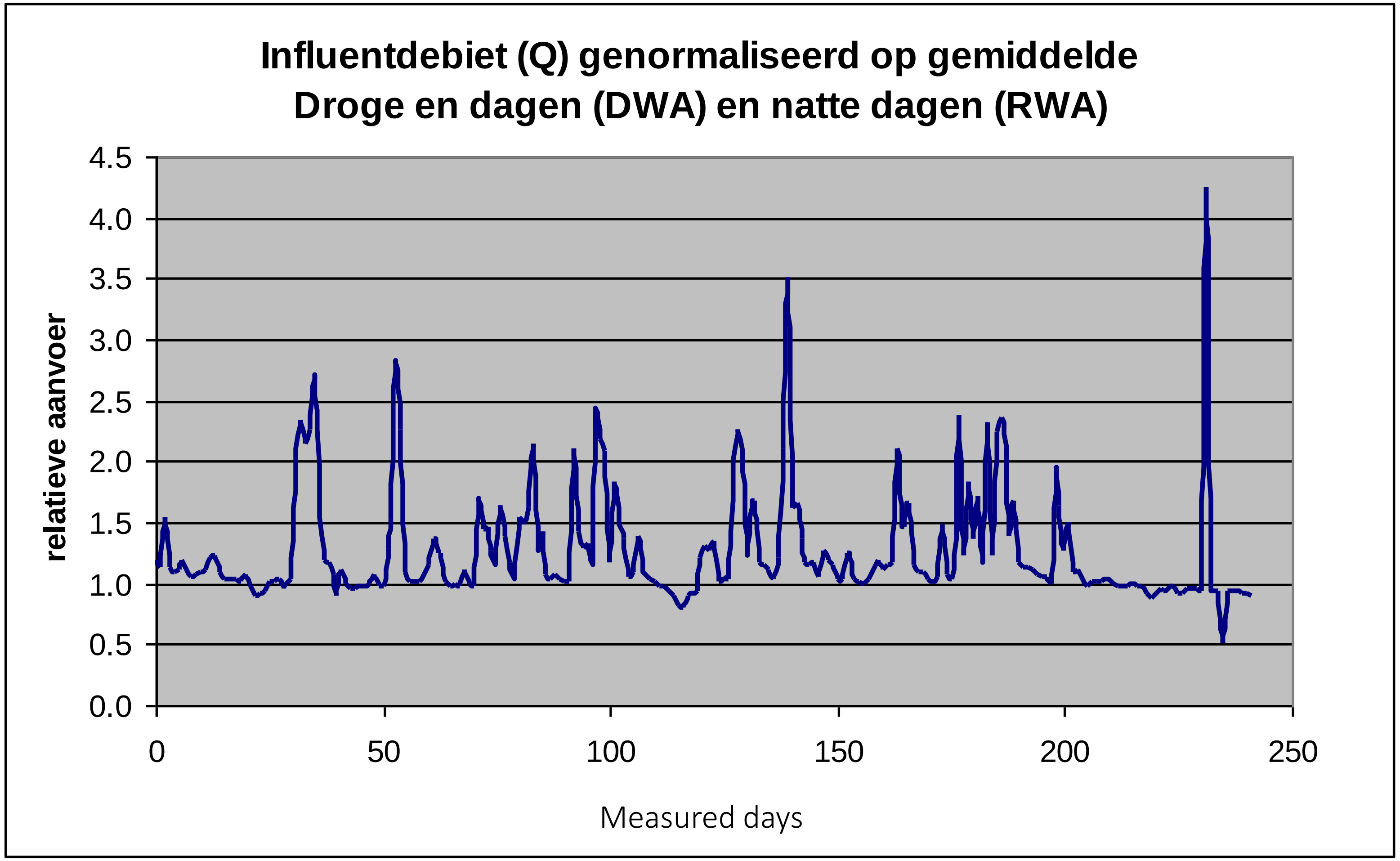
The BOD model



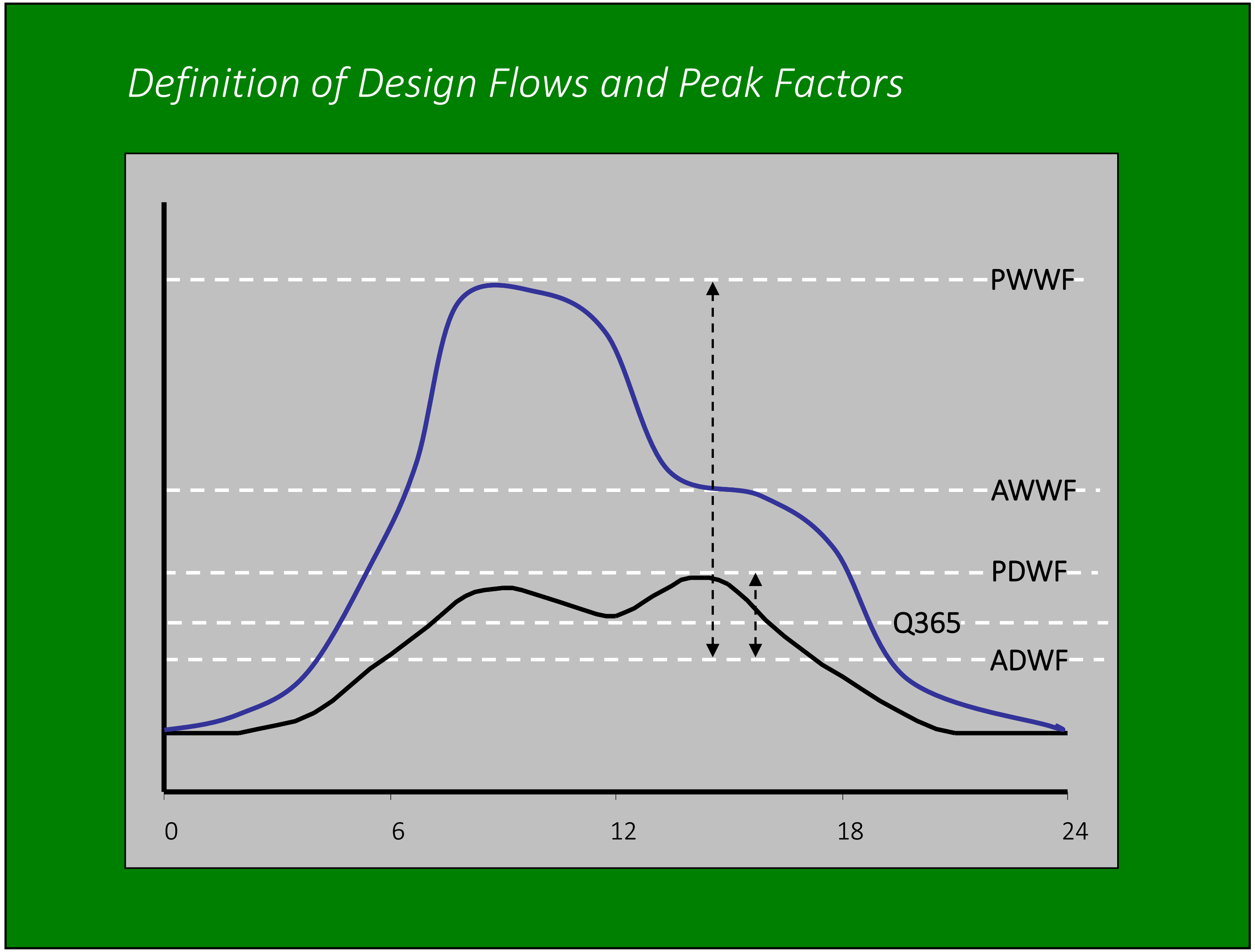
Typical Influent flow data

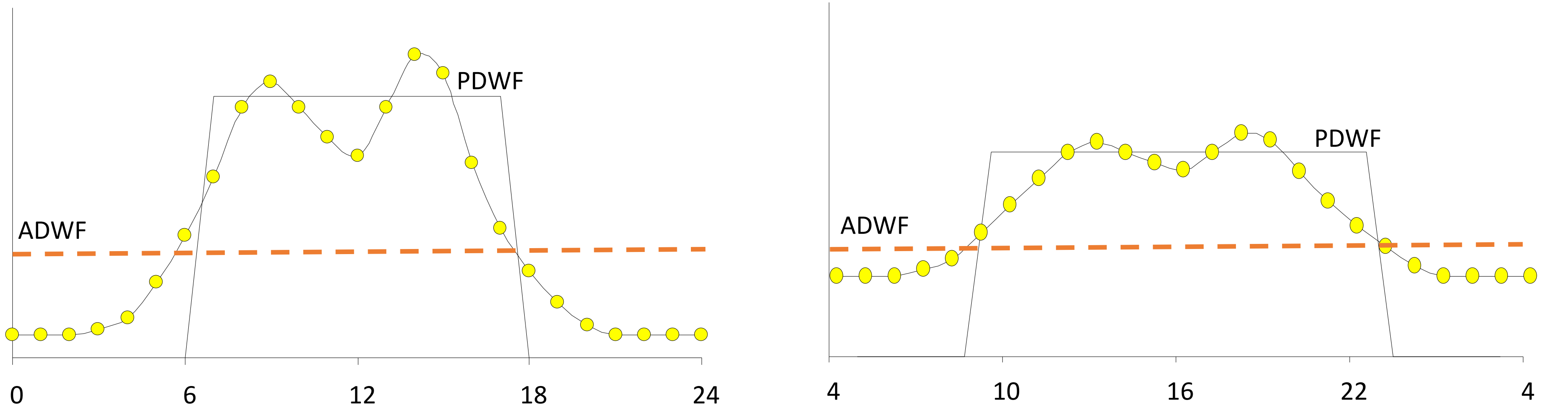
Variation of influent flow (250 days)

Flow relative to yearly average (100%)



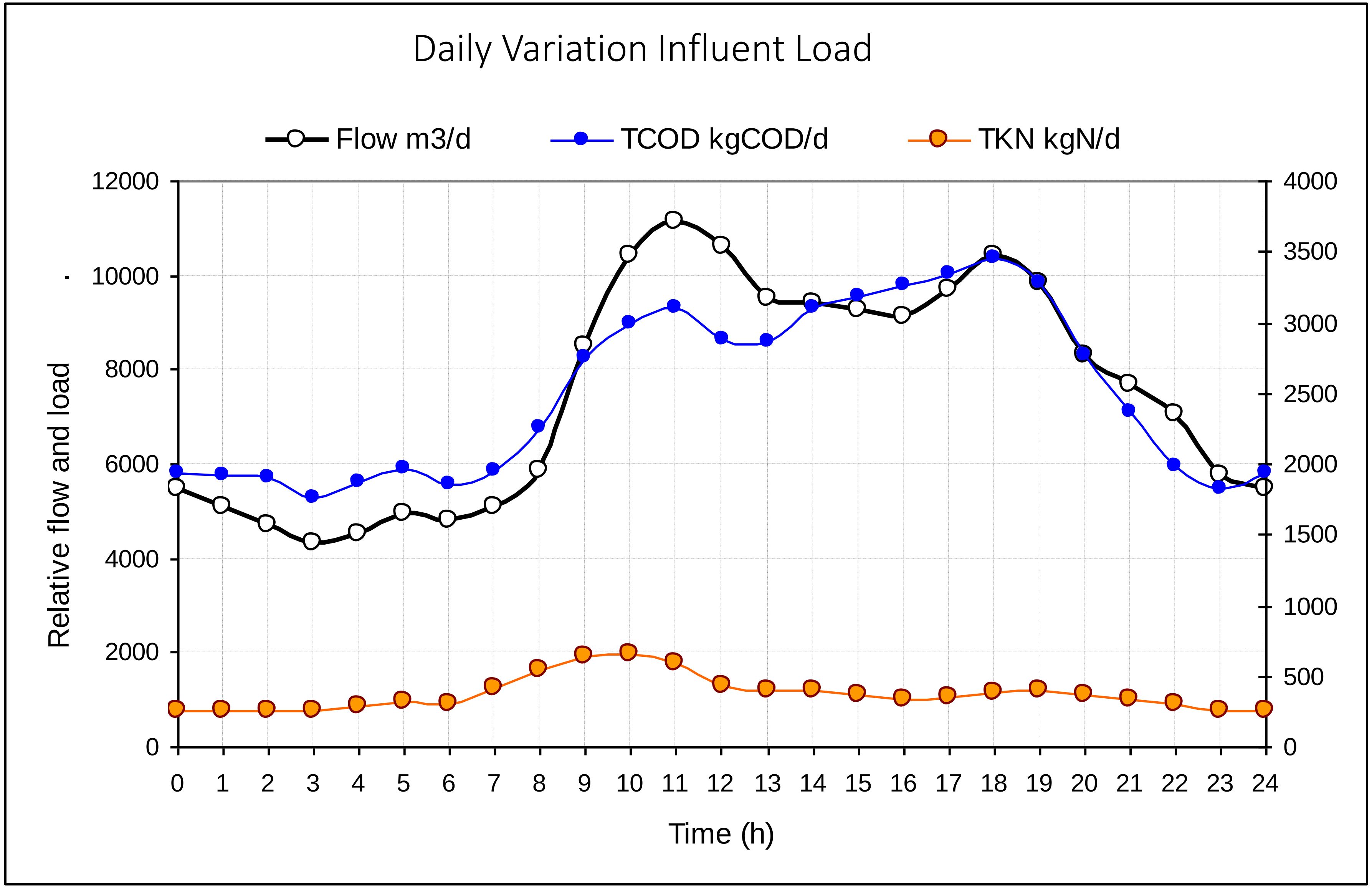
Design flows; a designers choice…! Use standards.



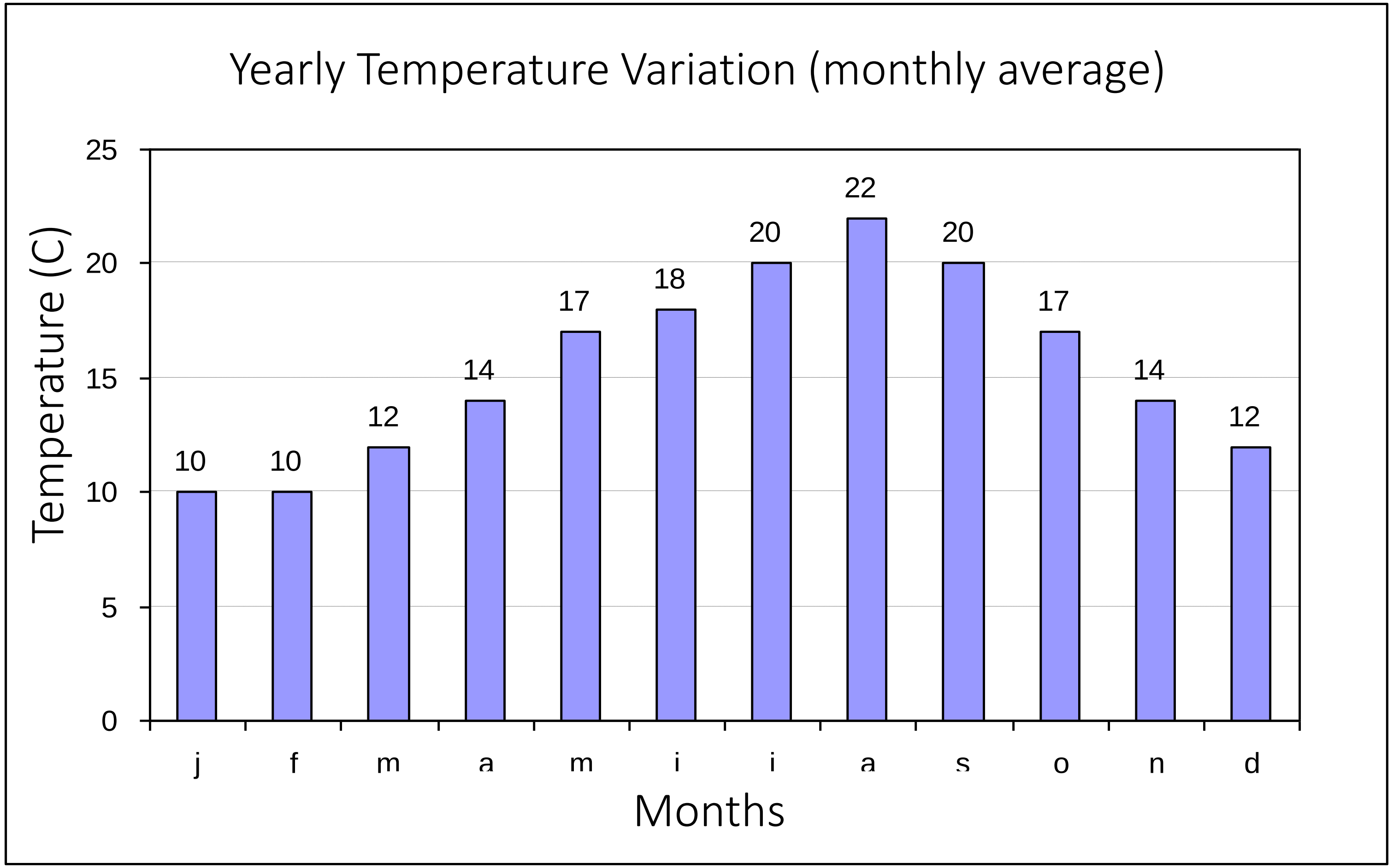


PDWF
ADWF
0
6
12
18
24
PDWF
ADWF
4
10
16
22
4

Typical 24h Influent flow and load



Typical yearly temperature variation



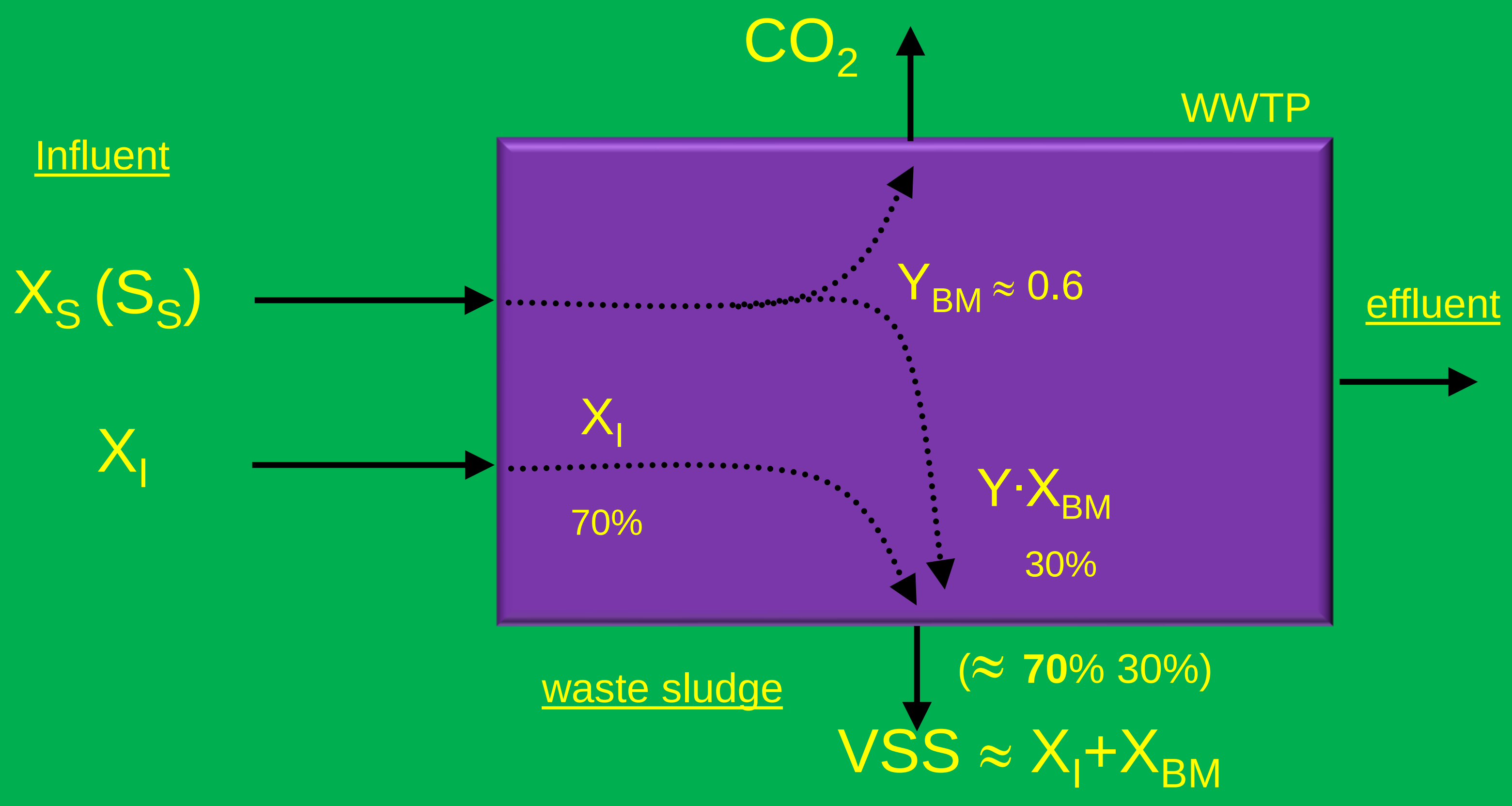
- Design temperature biology (nitrification in winter)?
- Design temperature aeration?
- Design safety factor?
- Use design standards!

Typical effluent requirement

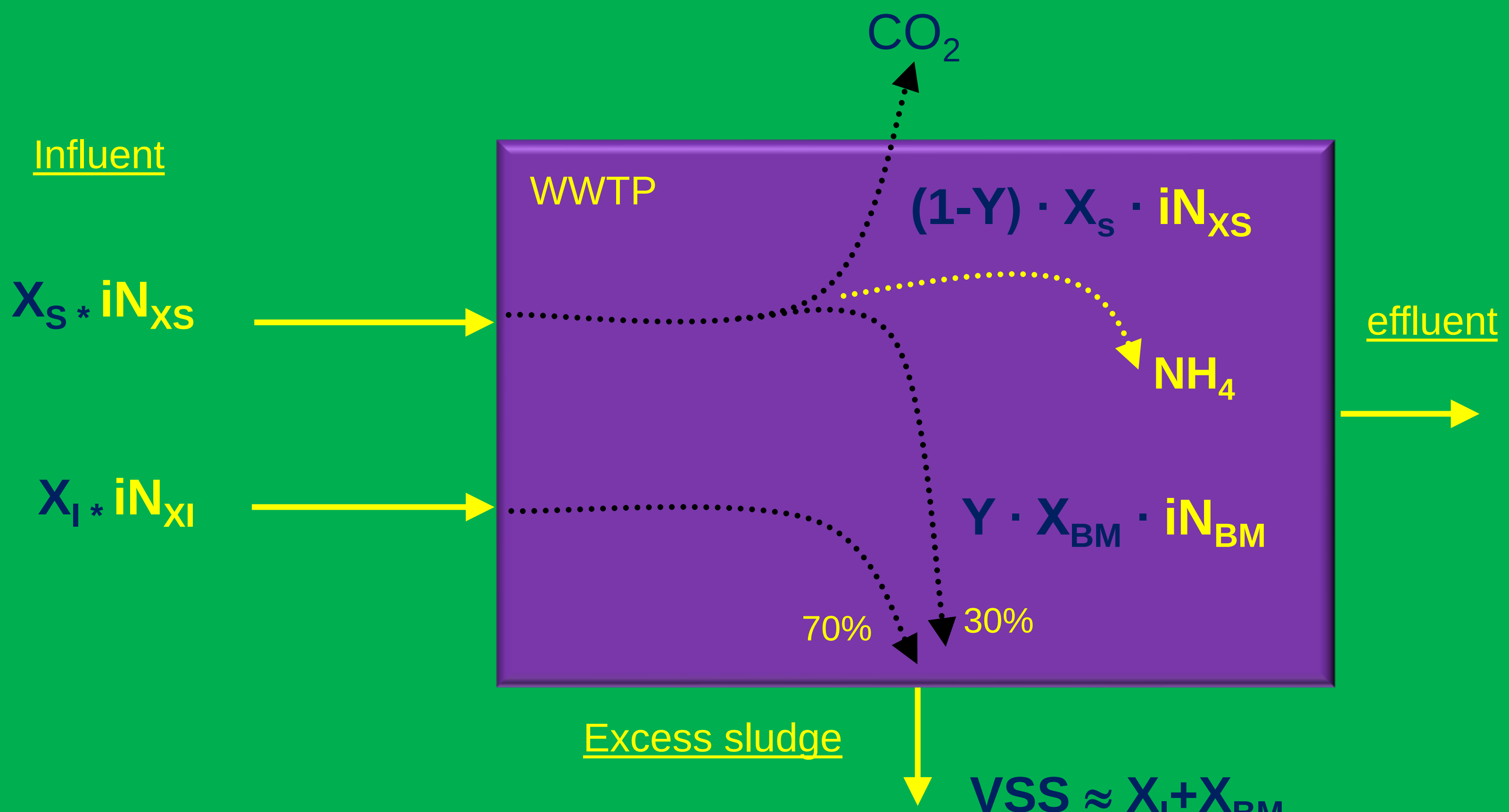
• N-total	< 10-30	mgN/l
• NH4	< 1-2	mgN/l
• P-total	< 0,5-2	mgP/l
• COD	< 50-150	mgCOD/l
• BOD	< 5-50	mgBOD/l
• TSS	< 5-30	mgTSS/l

- pH / Alkalinity
- Turbidity (colour)
- Heavy metals
- Micro pollutants
- Temperature

Particulate COD to waste sludge

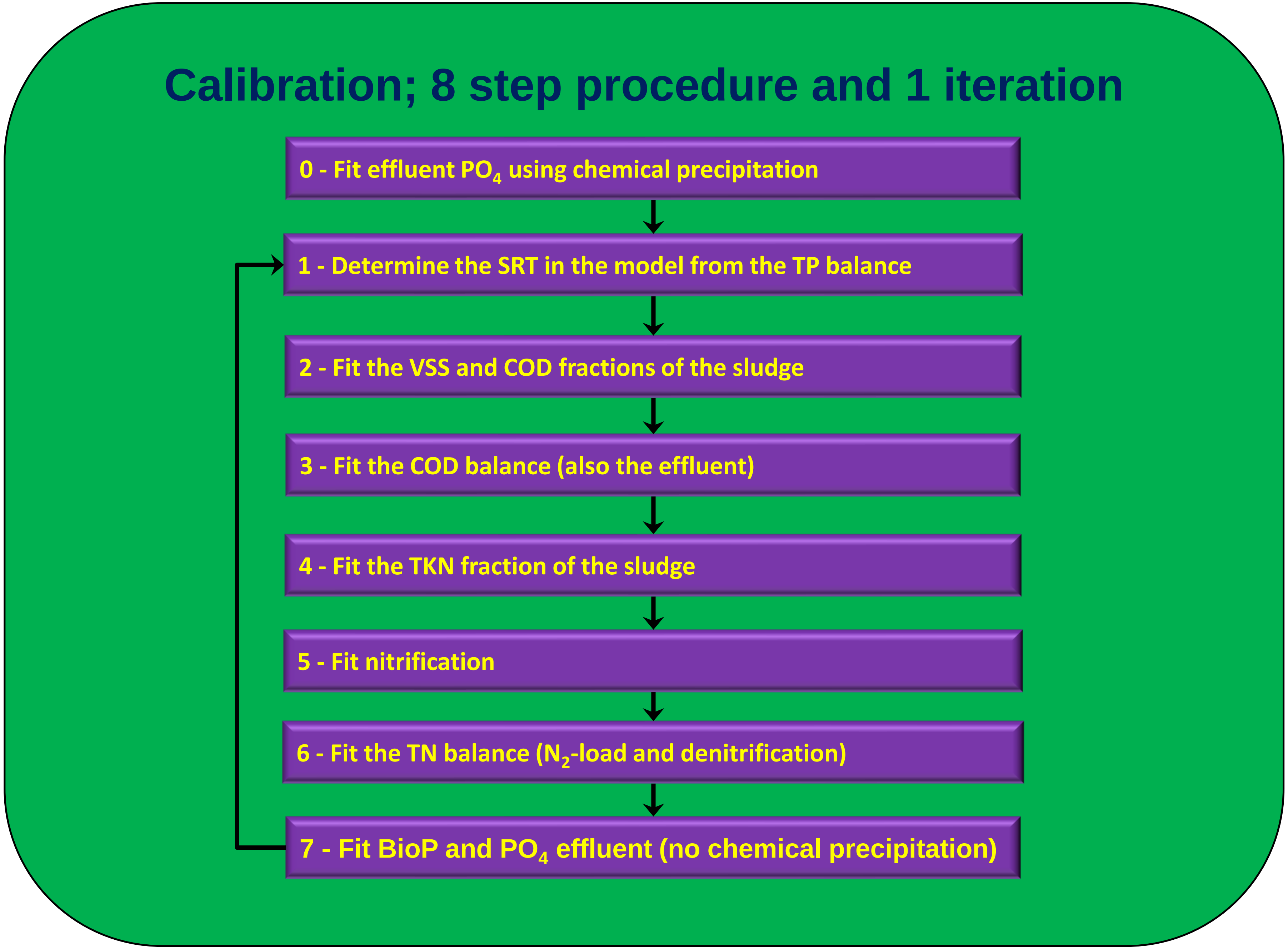


Particulate TKN to (waste) sludge



$VSS \approx X_I + X_{BM}$

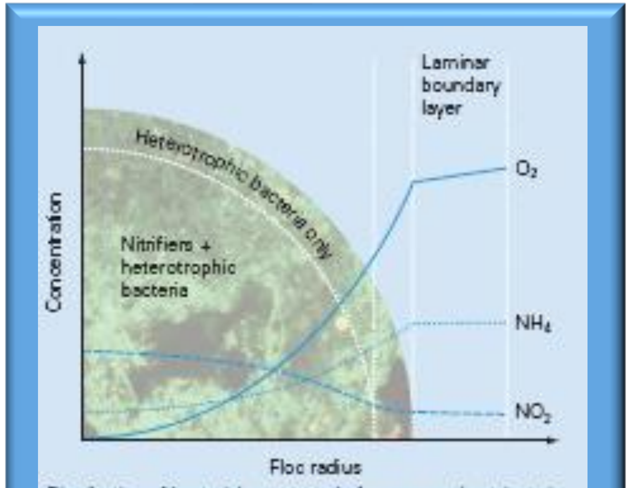
$TKN \approx X_I \cdot iN_{XI} + X_{BM} \cdot iN_{BM}$



Calibration; 8 step procedure and 1 iteration
0 - Fit effluent PO_4 using chemical precipitation
1 - Determine the SRT in the model from the TP balance
2 - Fit the VSS and COD fractions of the sludge
3 - Fit the COD balance (also the effluent)
4 - Fit the TKN fraction of the sludge
5 - Fit nitrification
6 - Fit the TN balance (N_2-load and denitrification)
7 - Fit BioP and PO_4 effluent (no chemical precipitation)

Fixing the COD, N and P balances in the model;

Closing the N balance with the denitrified load (N_2)

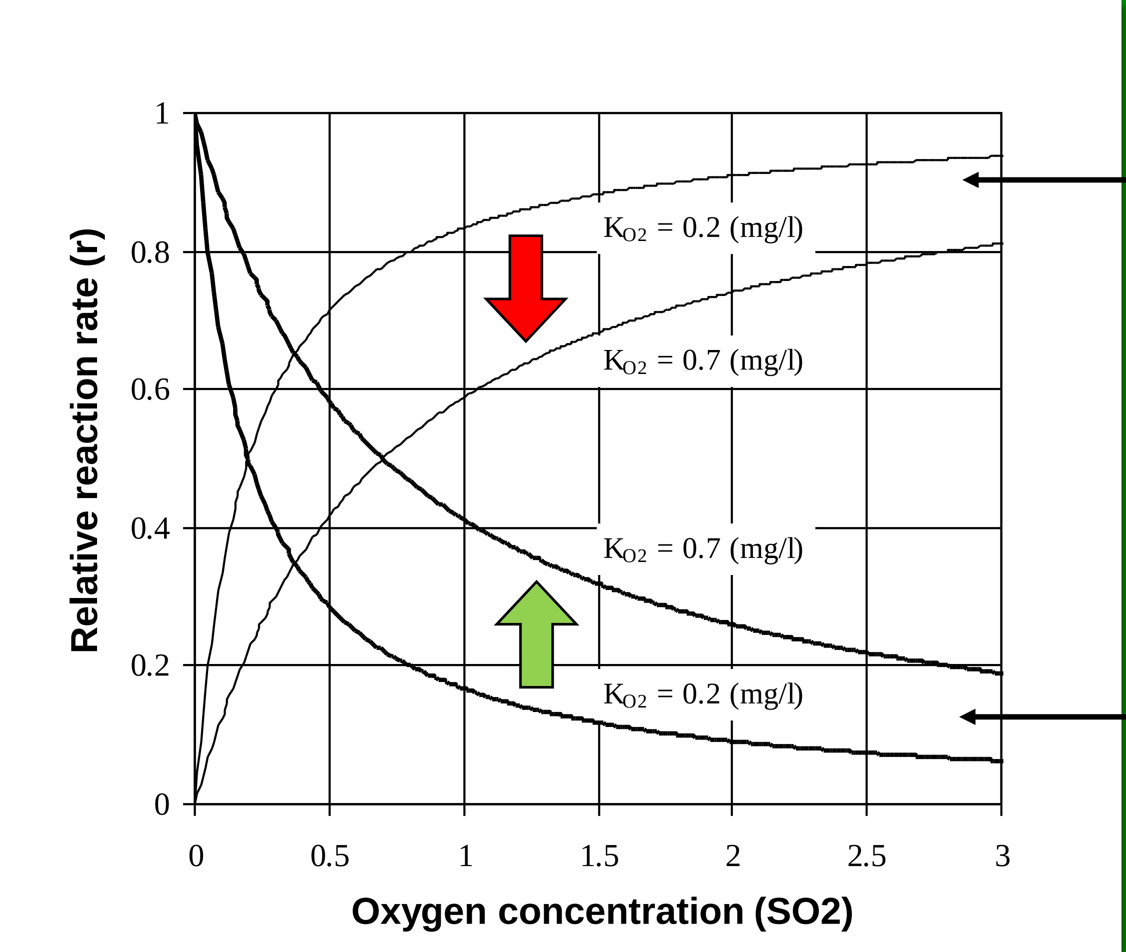


Distribution of bacterial groups and of oxygen and nutrients in the idealized floc.

Siegrist et al. 2006

- In ASM denitrification often is underestimated
- Simultaneous Nitrification/Denitrification (SND) is not properly predicted by the AS-model
- SND is caused by oxygen gradients
- Non-ideal mixing (e.g. oxygen gradients) and diffusion-limitations (e.g. flock size) are not modelled in ASM
- In the model the denitrified load (N_2) needs to be calibrated
- It is proposed to use the parameter K_{O2} to fit denitrification
- This is a black-box approach towards a combination of complex process

Fitting Simultaneous Nitrification and Denitrification in the model



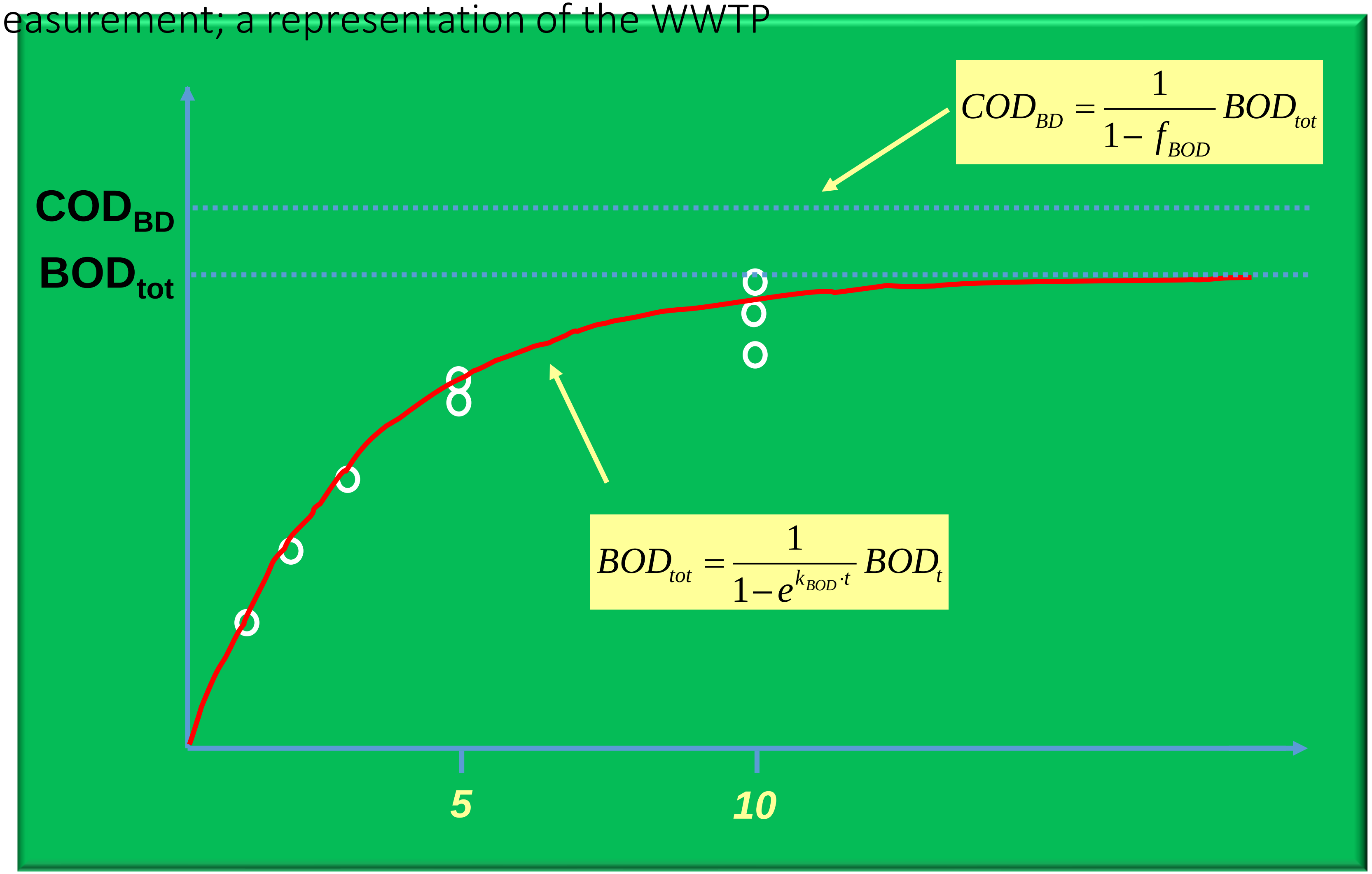
Aerobic saturation (Less Nitrification)

$$r = \frac{S_{O2}}{K_{O2} + S_{O2}}$$

Anoxic limitation (More Denitrification)

$$r = \frac{K_{O2}}{K_{O2} + S_{O2}}$$

The BOD measurement; a representation of the WWTP



BOD_{tot} is a model determined by parameters k_{BOD} en f_{BOD}

Appendix 4. Case study PONO BioWin configuration data

BioWin user and configuration data

Project details

Project name: Training BioWin Project ref.: Case study WWTP Poreč-North

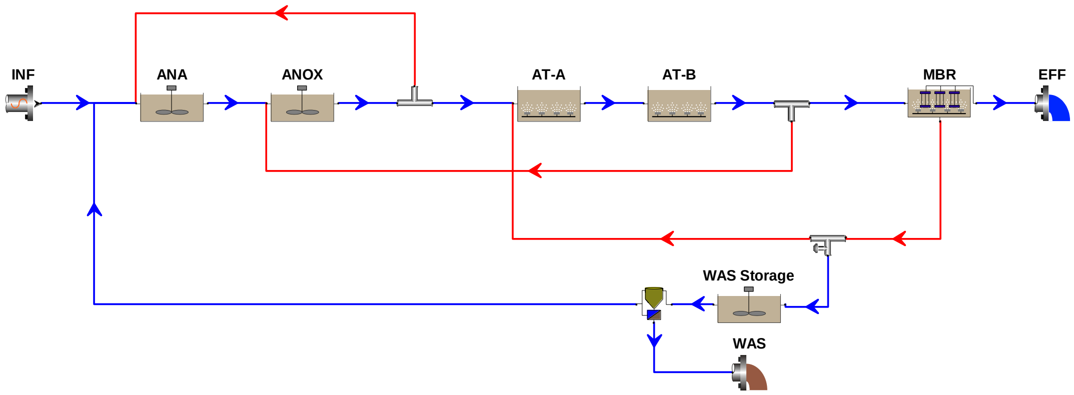
Plant name: WWTP Poreč-North (PONO) Username: Odvodnja Poreč

Created: 8-3-2022 Saved: 15-3-2022

Target SRT: 9,00 days SRT: ** days**

Temperature: 10,0°C

Flowsheet



Configuration information for all Bioreactor units

Physical data

Element name	Volume [m3]	Area [m2]	Depth [m]	# of diffusers
ANA	600,0000	114,2857	5,250	Un-aerated
ANOX	450,0000	85,7143	5,250	Un-aerated

AT-B	540,0000	102,8571	5,250	163
AT-A	540,0000	102,8571	5,250	163
WAS Storage	150,0000	37,5000	4,000	Un-aerated

Operating data Average (flow/time weighted as required)

Element name	Average DO Setpoint [mg/L]
ANA	0
ANOX	0
WAS Storage	0

Element name	Average Air flow rate [m3/hr (20C, 1 atm)]
AT-B	740,0
AT-A	177,9

Aeration equipment parameters

Element name	k1 in C = k1(PC)^0.25 + k2	k2 in C = k1(PC)^0.25 + k2	Y in Kla = C Usg ^ Y - Usg in [m3/(m2 d)]	Area of one diffuser	Diffuser mounting height	Min. air flow rate per diffuser m3/hr (20C, 1 atm)	Max. air flow rate per diffuser m3/hr (20C, 1 atm)	'A' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2	'B' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2	'C' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2
ANA	1,2400	0,8960	0,8880	0,0410	0,2500	0,5000	10,0000	3,0000	0	0
ANOX	1,2400	0,8960	0,8880	0,0410	0,2500	0,5000	10,0000	3,0000	0	0
AT-B	1,2400	0,8960	0,8880	0,0410	0,2500	0,5000	10,0000	3,0000	0	0
AT-A	1,2400	0,8960	0,8880	0,0410	0,2500	0,5000	10,0000	3,0000	0	0
WAS Storage	1,2400	0,8960	0,8880	0,0410	0,2500	0,5000	10,0000	3,0000	0	0

Configuration information for all Bioreactor - MBR units

Physical data

Element name	Volume [m3]	Area [m2]	Depth [m]	# of diffusers	# of cassettes	Displaced volume / cassette [m3/cassette]	Membrane area / cassette [m2/cassette]	Total displaced volume [m3]	Membrane surface area [m2]
MBR	240,0000	45,7143	5,250	320	8,00	1,690	1516,18	13,52	12129,44

Operating data Average (flow/time weighted as required)

Element name	Split method	Average Split specification
MBR	Flowrate [Under]	36500

Aeration equipment parameters

Element name	k1 in C = k1(PC)^0.25 + k2	k2 in C = k1(PC)^0.25 + k2	Y in Kla = C Usg ^ Y - Usg in [m3/(m2 d)]	Area of one diffuser	Diffuser mounting height	Min. air flow rate per diffuser m3/hr (20C, 1 atm)	Max. air flow rate per diffuser m3/hr (20C, 1 atm)	'A' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2	'B' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2	'C' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2
MBR	0,0500	0,3800	1,0000	0,0500	0,2500	2,0000	50,0000	1,0000	0	0

Element name	Surface pressure [kPa]	Fractional effective saturation depth (Fed) [-]
MBR	101,3250	0,3000

Element name	Supply gas CO2 content [vol. %]	Supply gas O2 [vol. %]	Off-gas CO2 [vol. %]	Off-gas O2 [vol. %]	Off-gas H2 [vol. %]	Off-gas NH3 [vol. %]	Off-gas CH4 [vol. %]	Off-gas N2O [vol. %]	Surface turbulence factor [-]
MBR	0,0400	20,9500	1,2000	19,9000	0	0	0	0	2,0000

Configuration information for all Influent - COD units

Operating data Average (flow/time weighted as required)

Element name	INF
Flow	1804,92
COD - Total mgCOD/L	833,73
N - Total Kjeldahl Nitrogen mgN/L	97,00
P - Total P mgP/L	9,87
S - Total S mgS/L	10,00
N - Nitrate mgN/L	0,10
pH	7,90
Alkalinity mmol/L	7,46
ISS Total mgISS/L	21,29
Metal soluble - Calcium mg/L	80,00
Metal soluble - Magnesium mg/L	15,00
Gas - Dissolved oxygen mg/L	0,10

Element name	INF
Fbs - Readily biodegradable (including Acetate) [gCOD/g of total COD]	0,3970
Fac - Acetate [gCOD/g of readily biodegradable COD]	0,2194
Fxsp - Non-colloidal slowly biodegradable [gCOD/g of slowly degradable COD]	0,7088
Fus - Unbiodegradable soluble [gCOD/g of total COD]	0,0383
Fup - Unbiodegradable particulate [gCOD/g of total COD]	0,1700
Fcel - Cellulose fraction of unbiodegradable particulate [gCOD/gCOD]	0,5000
Fna - Ammonia [gNH3-N/gTKN]	0,7921
Fnox - Particulate organic nitrogen [gN/g Organic N]	0,5000
Fnus - Soluble unbiodegradable TKN [gN/gTKN]	0
FupN - N:COD ratio for unbiodegradable part. COD [gN/gCOD]	0,0700
Fpo4 - Phosphate [gPO4-P/gTP]	0,5745
FupP - P:COD ratio for unbiodegradable part. COD [gP/gCOD]	0,0220
Fsr - Reduced sulfur [H2S] [gS/gS]	0,1500

FZbh - Ordinary heterotrophic COD fraction [gCOD/g of total COD]	0,0200
FZbm - Methylotrophic COD fraction [gCOD/g of total COD]	1,000E-4
FZao - Ammonia oxidizing COD fraction [gCOD/g of total COD]	1,000E-4
FZno - Nitrite oxidizing COD fraction [gCOD/g of total COD]	1,000E-4
FZaao - Anaerobic ammonia oxidizing COD fraction [gCOD/g of total COD]	1,000E-4
FZppa - Phosphorus accumulating COD fraction [gCOD/g of total COD]	1,000E-4
FZpa - Propionic acetogenic COD fraction [gCOD/g of total COD]	1,000E-4
FZam - Acetoclastic methanogenic COD fraction [gCOD/g of total COD]	1,000E-4
FZhm - Hydrogenotrophic methanogenic COD fraction [gCOD/g of total COD]	1,000E-4
FZso - Sulfur oxidizing COD fraction [gCOD/g of total COD]	1,000E-4
FZsrpa - Sulfur reducing propionic acetogenic COD fraction [gCOD/g of total COD]	1,000E-4
FZsra - Sulfur reducing acetotrophic COD fraction [gCOD/g of total COD]	1,000E-4
FZsrh - Sulfur reducing hydrogenotrophic COD fraction [gCOD/g of total COD]	1,000E-4
FZe - Endogenous products COD fraction [gCOD/g of total COD]	0

Configuration information for all Separator - Cyclone (dewatering) units

Operating data Average (flow/time weighted as required)

Element name	Split method	Average Split specification
Dewatering	Fraction	0,02

Element name	Percent removal
Dewatering	98,00

Configuration information for all Splitter units

Operating data Average (flow/time weighted as required)

Element name	Split method	Average Split specification
ANA-R	Flowrate [Side]	6900

ANOX-R	Flowrate [Side]	14600
WAS Splitter	Flowrate [Side]	42,875

BioWin Album

Album page - Page 2

Elements	EFF
Total suspended solids [mg/L]	0
BOD - Total Carbonaceous [mg/L]	1,15
COD - Total [mg/L]	48,92
N - Total N [mgN/L]	6,53
N - Ammonia [mgN/L]	0,99
N - Nitrate [mgN/L]	3,97
P - Total P [mgP/L]	0,07
P - Soluble PO4-P [mgP/L]	0,07

Album page - Sludge composition

Elements	ANA	ANOX	AT-B	MBR (U)	WAS
Total suspended solids [mg/L]	6188,50	7764,45	8706,03	9121,98	0
Volatile suspended solids [mg/L]	5309,81	6576,87	7333,65	7682,51	0
ISS Total [mg/L]	878,69	1187,58	1372,38	1439,47	0
COD - Total [mg/L]	7144,70	8811,97	9817,03	10281,49	0
COD - Particulate [mg/L]	7086,31	8765,32	9768,40	10232,57	0
N - Total Kjeldahl Nitrogen [mgN/L]	405,25	485,88	534,16	558,78	0
N - Particulate TKN [mgN/L]	378,73	474,13	530,93	556,37	0
N - Ammonia [mgN/L]	25,53	10,66	1,88	0,99	0
N - Nitrate [mgN/L]	0,00	0,10	3,14	3,97	0
N - Nitrite [mgN/L]	0,00	0,01	0,27	0,15	0
P - Total P [mgP/L]	211,18	263,84	295,23	309,37	0
P - Soluble PO4-P [mgP/L]	36,32	14,01	0,50	0,07	0
Biomass - Ammonia oxidizing [mgCOD/L]	59,40	75,23	84,80	88,92	0

Biomass - Ordinary heterotrophic [mgCOD/L]	1126,32	1418,67	1595,02	1672,49	0

Elements	INF
Total suspended solids [mg/L]	295,93
Volatile suspended solids [mg/L]	274,64
ISS Total [mg/L]	21,29
BOD - Total Carbonaceous [mg/L]	381,39
BOD - Filtered Carbonaceous [mg/L]	276,05
COD - Total [mg/L]	833,73
COD - Particulate [mg/L]	380,13
COD - Filtered [mg/L]	453,60
N - Total Kjeldahl Nitrogen [mgN/L]	97,00
N - Particulate TKN [mgN/L]	13,18
N - Ammonia [mgN/L]	76,83
N - Nitrate [mgN/L]	0,10
N - Nitrite [mgN/L]	0
P - Total P [mgP/L]	9,87
P - Soluble PO4-P [mgP/L]	5,67

Elements	INF
Total suspended solids [kg /d]	534,13
Volatile suspended solids [kg /d]	495,70
ISS Total [kg /d]	38,43
BOD - Total Carbonaceous [kg /d]	688,38
BOD - Filtered Carbonaceous [kg /d]	498,24
COD - Total [kg /d]	1504,82
COD - Particulate [kg /d]	686,10
COD - Filtered [kg /d]	818,72
N - Total Kjeldahl Nitrogen [kg N/d]	175,08
N - Particulate TKN [kg N/d]	23,79
N - Ammonia [kg N/d]	138,68

N - Nitrate [kg N/d]	0,18
N - Nitrite [kg N/d]	0
P - Total P [kg P/d]	17,82
P - Soluble PO4-P [kg P/d]	10,24

Elements	Flow [m3/d]
INF	1804,92
EFF	1747,72
ANA-R (U)	6900,00
ANOX-R (U)	14600,00
MBR (U)	36500,00
WAS	2,00

Global Parameters

Common

Name	Default	Value	
Hydrolysis rate [1/d]	2,1000	2,1000	1,0290
Hydrolysis half sat. [-]	0,0600	0,0600	1,0000
External organics hydrolysis rate [1/d]	2,1000	2,1000	1,0290
External organics hydrolysis half sat. [-]	0,0600	0,0600	1,0000
Anoxic hydrolysis factor [-]	0,2800	0,2800	1,0000
Anaerobic hydrolysis factor (AS) [-]	0,0400	0,0400	1,0000
Anaerobic hydrolysis factor (AD) [-]	0,5000	0,5000	1,0000
Adsorption rate of colloids [L/(mgCOD d)]	0,1500	0,1500	1,0290
Ammonification rate [L/(mgCOD d)]	0,0800	0,0800	1,0290
Assimilative nitrate/nitrite reduction rate [1/d]	0,5000	0,5000	1,0000
Endogenous products decay rate [1/d]	0	0	1,0000

Ammonia oxidizing

Name	Default	Value	
Max. spec. growth rate [1/d]	0,9000	0,9000	1,0720
Substrate (NH4) half sat. [mgN/L]	0,7000	0,7000	1,0000
Byproduct NH4 logistic slope [-]	50,0000	50,0000	1,0000
Byproduct NH4 inflection point [mgN/L]	1,4000	1,4000	1,0000
Denite DO half sat. [mg/L]	0,1000	0,1000	1,0000
Denite HNO2 half sat. [mgN/L]	5,000E-6	5,000E-6	1,0000
Aerobic decay rate [1/d]	0,1700	0,1700	1,0290
Anoxic/anaerobic decay rate [1/d]	0,0800	0,0800	1,0290
KiHNO2 [mmol/L]	5,000E-3	5,000E-3	1,0000

Nitrite oxidizing

Name	Default	Value	
Max. spec. growth rate [1/d]	0,7000	1,0000	1,0600
Substrate (NO2) half sat. [mgN/L]	0,1000	0,1000	1,0000
Aerobic decay rate [1/d]	0,1700	0,1700	1,0290
Anoxic/anaerobic decay rate [1/d]	0,0800	0,0800	1,0290
KiNH3 [mmol/L]	0,0750	0,0750	1,0000

Anaerobic ammonia oxidizing

Name	Default	Value	
Max. spec. growth rate [1/d]	0,2000	0,2000	1,1000
Substrate (NH4) half sat. [mgN/L]	2,0000	2,0000	1,0000
Substrate (NO2) half sat. [mgN/L]	1,0000	1,0000	1,0000
Aerobic decay rate [1/d]	0,0190	0,0190	1,0290
Anoxic/anaerobic decay rate [1/d]	9,500E-3	9,500E-3	1,0290
Ki Nitrite [mgN/L]	1000,0000	1000,0000	1,0000
Nitrite sensitivity constant [L / (d mgN)]	0,0160	0,0160	1,0000

Ordinary heterotrophic

Name	Default	Value	
Max. spec. growth rate [1/d]	3,2000	3,2000	1,0290
Substrate half sat. [mgCOD/L]	5,0000	5,0000	1,0000
Anoxic growth factor [-]	0,5000	0,5000	1,0000
Denite N2 producers (NO3 or NO2) [-]	0,5000	0,5000	1,0000
Aerobic decay rate [1/d]	0,6200	0,6200	1,0290
Anoxic decay rate [1/d]	0,2330	0,2330	1,0290
Anaerobic decay rate [1/d]	0,1310	0,1310	1,0290
Fermentation rate [1/d]	1,6000	1,6000	1,0290
Fermentation half sat. [mgCOD/L]	5,0000	5,0000	1,0000
Fermentation growth factor (AS) [-]	0,2500	0,2500	1,0000
Free nitrous acid inhibition [mol/L]	1,000E-7	1,000E-7	1,0000

Heterotrophic on industrial COD

Name	Default	Value	
Maximum specific growth rate on Ind #1 COD [1/d]	4,3000	4,3000	1,0290
Substrate (Ind #1) half sat. [mgCOD/L]	1,0000	1,0000	1,0000
Inhibition coefficient for Ind #1 [mgCOD/L]	60,0000	60,0000	1,0000
Anaerobic growth factor for Ind #1 [mgCOD/L]	0,0500	0,0500	1,0000
Maximum specific growth rate on Ind #2 COD [1/d]	1,5000	1,5000	1,0290
Substrate (Ind #2) half sat. [mgCOD/L]	30,0000	30,0000	1,0000
Inhibition coefficient for Ind #2 [mgCOD/L]	3000,0000	3000,0000	1,0000
Anaerobic growth factor for Ind #2 [mgCOD/L]	0,0500	0,0500	1,0000
Maximum specific growth rate on Ind #3 COD [1/d]	4,3000	4,3000	1,0290
Substrate (Ind #3) half sat. [mgCOD/L]	1,0000	1,0000	1,0000
Inhibition coefficient for Ind #3 COD [mgCOD/L]	60,0000	60,0000	1,0000
Anaerobic growth factor for Ind #3 [mgCOD/L]	0,0500	0,0500	1,0000
Maximum specific growth rate on adsorbed hydrocarbon COD [1/d]	2,0000	2,0000	1,0290
Substrate (adsorbed hydrocarbon) half sat. [-]	0,1500	0,1500	1,0000
Anaerobic growth factor for adsorbed hydrocarbons [mgCOD/L]	0,0100	0,0100	1,0000
Adsorption rate of soluble hydrocarbons [l/(mgCOD d)]	0,2000	0,2000	1,0000

Methylotrophic

Name	Default	Value	
Max. spec. growth rate [1/d]	1,3000	1,3000	1,0720
Methanol half sat. [mgCOD/L]	0,5000	0,5000	1,0000
Denite N2 producers (NO3 or NO2) [-]	0,5000	0,5000	1,0000
Aerobic decay rate [1/d]	0,0400	0,0400	1,0290
Anoxic/anaerobic decay rate [1/d]	0,0300	0,0300	1,0290
Free nitrous acid inhibition [mmol/L]	1,000E-7	1,000E-7	1,0000

Phosphorus accumulating

Name	Default	Value	
Max. spec. growth rate [1/d]	0,9500	0,9500	1,0000
Max. spec. growth rate, P-limited [1/d]	0,4200	0,4200	1,0000
Substrate half sat. [mgCOD(PHB)/mgCOD(Zbp)]	0,1000	0,1000	1,0000
Substrate half sat., P-limited [mgCOD(PHB)/mgCOD(Zbp)]	0,0500	0,0500	1,0000
Magnesium half sat. [mgMg/L]	0,1000	0,1000	1,0000
Cation half sat. [mmol/L]	0,1000	0,1000	1,0000
Calcium half sat. [mgCa/L]	0,1000	0,1000	1,0000
Aerobic/anoxic decay rate [1/d]	0,1000	0,1000	1,0000
Aerobic/anoxic maintenance rate [1/d]	0	0	1,0000
Anaerobic decay rate [1/d]	0,0400	0,0400	1,0000
Anaerobic maintenance rate [1/d]	0	0	1,0000
Sequestration rate [1/d]	4,5000	4,5000	1,0000
Anoxic growth factor [-]	0,3300	0,3300	1,0000

Propionic acetogenic

Methanogenic

Name	Default	Value	
Acetoclastic max. spec. growth rate [1/d]	0,3000	0,3000	1,0290

H2-utilizing max. spec. growth rate [1/d]	1,4000	1,4000	1,0290
Acetoclastic substrate half sat. [mgCOD/L]	100,0000	100,0000	1,0000
Acetoclastic methanol half sat. [mgCOD/L]	0,5000	0,5000	1,0000
H2-utilizing CO2 half sat. [mmol/L]	0,1000	0,1000	1,0000
H2-utilizing substrate half sat. [mgCOD/L]	1,0000	1,0000	1,0000
H2-utilizing methanol half sat. [mgCOD/L]	0,5000	0,5000	1,0000
Acetoclastic propionic inhibition [mgCOD/L]	10000,0000	10000,0000	1,0000
Acetoclastic anaerobic decay rate [1/d]	0,1300	0,1300	1,0290
Acetoclastic aerobic/anoxic decay rate [1/d]	0,6000	0,6000	1,0290
H2-utilizing anaerobic decay rate [1/d]	0,1300	0,1300	1,0290
H2-utilizing aerobic/anoxic decay rate [1/d]	2,8000	2,8000	1,0290

Sulfur oxidizing

Name	Default	Value	
Maximum specific growth rate (sulfide) [1/d]	0,7500	0,7500	1,0290
Maximum specific growth rate (sulfur) [1/d]	0,1000	0,1000	1,0290
Substrate (H2S) half sat. [mgS/L]	1,0000	1,0000	1,0000
Substrate (sulfur) half sat. [mgS/L]	1,0000	1,0000	1,0000
Anoxic growth factor [-]	0,5000	0,5000	1,0000
Decay rate [1/d]	0,0400	0,0400	1,0290

Sulfur reducing

pH

Name	Default	Value
Ordinary heterotrophic low pH limit [-]	4,0000	4,0000
Ordinary heterotrophic high pH limit [-]	10,0000	10,0000
Methylotrophic low pH limit [-]	4,0000	4,0000
Methylotrophic high pH limit [-]	10,0000	10,0000
Autotrophic low pH limit [-]	5,5000	5,5000
Autotrophic high pH limit [-]	9,5000	9,5000

Phosphorus accumulating low pH limit [-]	4,0000	4,0000
Phosphorus accumulating high pH limit [-]	10,0000	10,0000
Ordinary heterotrophic low pH limit (anaerobic) [-]	5,5000	5,5000
Ordinary heterotrophic high pH limit (anaerobic) [-]	8,5000	8,5000
Propionic acetogenic low pH limit [-]	4,0000	4,0000
Propionic acetogenic high pH limit [-]	10,0000	10,0000
Acetoclastic methanogenic low pH limit [-]	5,0000	5,0000
Acetoclastic methanogenic high pH limit [-]	9,0000	9,0000
H2-utilizing methanogenic low pH limit [-]	5,0000	5,0000
H2-utilizing methanogenic high pH limit [-]	9,0000	9,0000

Switches

Name	Default	Value
Ordinary heterotrophic DO half sat. [mgO2/L]	0,1500	0,5000
Phosphorus accumulating DO half sat. [mgO2/L]	0,0500	0,0500
Anoxic/anaerobic NOx half sat. [mgN/L]	0,1500	0,1500
Ammonia oxidizing DO half sat. [mgO2/L]	0,2500	0,2500
Nitrite oxidizing DO half sat. [mgO2/L]	0,5000	0,5000
Anaerobic ammonia oxidizing DO half sat. [mgO2/L]	0,0100	0,0100
Sulfur oxidizing sulfate pathway DO half sat. [mgO2/L]	0,2500	0,2500
Sulfur oxidizing sulfur pathway DO half sat. [mgO2/L]	0,0500	0,0500
Anoxic NO3(->NO2) half sat. [mgN/L]	0,1000	0,1000
Anoxic NO3(->N2) half sat. [mgN/L]	0,0500	0,0500
Anoxic NO2(->N2) half sat. (mgN/L)	0,0100	0,0100
NH3 nutrient half sat. [mgN/L]	5,000E-3	5,000E-3
PolyP half sat. [mgP/mgCOD]	0,0100	0,0100
VFA sequestration half sat. [mgCOD/L]	5,0000	5,0000
P uptake half sat. [mgP/L]	0,1500	0,1500
P nutrient half sat. [mgP/L]	1,000E-3	1,000E-3
Autotrophic CO2 half sat. [mmol/L]	0,1000	0,1000
H2 low/high half sat. [mgCOD/L]	1,0000	1,0000

Propionic acetogenic H2 inhibition [mgCOD/L]	5,0000	5,0000
Synthesis anion/cation half sat. [meq/L]	0,0100	0,0100

Common

Name	Default	Value
Biomass/Endog Ca content (gCa/gCOD)	3,912E-3	3,912E-3
Biomass/Endog Mg content (gMg/gCOD)	3,912E-3	3,912E-3
Biomass/Endog other cations content (mol/gCOD)	5,115E-4	5,115E-4
Biomass/Endog other Anions content (mol/gCOD)	1,410E-4	1,410E-4
N in endogenous residue [mgN/mgCOD]	0,0700	0,0700
P in endogenous residue [mgP/mgCOD]	0,0220	0,0220
Ca content of slowly biodegradabe (gCa/gCOD)	3,912E-3	3,912E-3
Mg content of slowly biodegradabe (gMg/gCOD)	3,700E-4	3,700E-4
Endogenous residue COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200
Particulate substrate COD:VSS ratio [mgCOD/mgVSS]	1,6327	1,5000
Particulate inert COD:VSS ratio [mgCOD/mgVSS]	1,6000	1,1000
Cellulose COD:VSS ratio [mgCOD/mgVSS]	1,4000	1,4000
External organic COD:VSS ratio [mgCOD/mgVSS]	1,6000	1,6000
Molecular weight of other anions [mg/mmol]	35,5000	35,5000
Molecular weight of other cations [mg/mmol]	39,0983	39,0983

Ammonia oxidizing

Name	Default	Value
Yield [mgCOD/mgN]	0,1500	0,1500
Denite NO2 fraction as TEA [-]	0,5000	0,5000
Byproduct NH4 fraction to N2O [-]	2,500E-3	2,500E-3
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Nitrite oxidizing

Name	Default	Value
Yield [mgCOD/mgN]	0,0900	0,0900
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Anaerobic ammonia oxidizing

Name	Default	Value
Yield [mgCOD/mgN]	0,1140	0,1140
Nitrate production [mgN/mgBiomassCOD]	2,2800	2,2800
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Ordinary heterotrophic

Name	Default	Value
Yield (aerobic) [-]	0,6660	0,6660
Yield (fermentation, low H2) [-]	0,1000	0,1000
Yield (fermentation, high H2) [-]	0,1000	0,1000
H2 yield (fermentation low H2) [-]	0,3500	0,3500
H2 yield (fermentation high H2) [-]	0	0
Propionate yield (fermentation, low H2) [-]	0	0
Propionate yield (fermentation, high H2) [-]	0,7000	0,7000
CO2 yield (fermentation, low H2) [-]	0,7000	0,7000
CO2 yield (fermentation, high H2) [-]	0	0
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220

Endogenous fraction - aerobic [-]	0,0800	0,0800
Endogenous fraction - anoxic [-]	0,1030	0,1030
Endogenous fraction - anaerobic [-]	0,1840	0,1840
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200
Yield (anoxic) [-]	0,5400	0,5400
Yield propionic (aerobic) [-]	0,6400	0,6400
Yield propionic (anoxic) [-]	0,4600	0,4600
Yield acetic (aerobic) [-]	0,6000	0,6000
Yield acetic (anoxic) [-]	0,4300	0,4300
Yield methanol (aerobic) [-]	0,5000	0,5000
Adsorp. max. [-]	1,0000	1,0000
Max fraction to N2O at high FNA over nitrate [-]	0,0500	0,0500
Max fraction to N2O at high FNA over nitrite [-]	0,1000	0,1000

Ordinary heterotrophic on industrial COD

Name	Default	Value
Yield Ind #1 COD (Aerobic) [-]	0,5000	0,5000
Yield Ind #1 COD (Anoxic) [-]	0,4000	0,4000
Yield Ind #1 COD (Anaerobic) [-]	0,0400	0,0400
COD:Mole ratio - Ind #1 COD [gCOD/Mol]	224,0000	224,0000
Yield Ind #2 COD (Aerobic) [-]	0,5000	0,5000
Yield Ind #2 COD (Anoxic) [-]	0,4000	0,4000
Yield Ind #2 COD (Anaerobic) [-]	0,0500	0,0500
COD:Mole ratio - Ind #2 COD [gCOD/Mol]	240,0000	240,0000
Yield on Ind #3 COD (Aerobic) [-]	0,5000	0,5000
Yield on Ind #3 COD (Anoxic) [-]	0,4000	0,4000
Yield on Ind #3 COD (Anaerobic) [-]	0,0400	0,0400
COD:Mole ratio - Ind #3 COD [gCOD/Mol]	288,0000	288,0000
Yield enmeshed hydrocarbons (Aerobic) [-]	0,5000	0,5000
Yield enmeshed hydrocarbons (Anoxic) [-]	0,4000	0,4000
Yield enmeshed hydrocarbons (Anaerobic) [-]	0,0400	0,0400

COD:Mole ratio - Hydrocarbon COD [gCOD/Mol]	336,0000	336,0000
Hydrocarbon COD:VSS ratio [mgCOD/mgVSS]	3,2000	3,2000
Max. hydrocarbon adsorp. ratio [-]	1,0000	1,0000
Yield of Ind #1 on Ind #3 COD (Aerobic) [-]	0	0
Yield of Ind #1 on Ind #3 COD (Anoxic) [-]	0	0
Hydrocarbon Yield on Ind #3 COD (Aerobic) [-]	0	0
Hydrocarbon Yield on Ind #3 COD (Anoxic) [-]	0	0

Methylotrophic

Name	Default	Value
Yield (anoxic) [-]	0,4000	0,4000
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200
Max fraction to N2O at high FNA over nitrate [-]	0,1000	0,1000
Max fraction to N2O at high FNA over nitrite [-]	0,1500	0,1500

Phosphorus accumulating

Name	Default	Value
Yield (aerobic) [-]	0,6390	0,6390
Yield (anoxic) [-]	0,5200	0,5200
Aerobic P/PHA uptake [mgP/mgCOD]	0,9300	0,9300
Anoxic P/PHA uptake [mgP/mgCOD]	0,3500	0,3500
Yield of PHA on Ac sequestration [-]	0,8890	0,8890
N in biomass [mgN/mgCOD]	0,0700	0,0700
N in sol. inert [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous part. [-]	0,2500	0,2500
Inert fraction of endogenous sol. [-]	0,2000	0,2000
P/Ac release ratio [mgP/mgCOD]	0,5100	0,5100

COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200
Yield of low PP [-]	0,9400	0,9400
Mg to P mole ratio in polyphosphate [mmolMg/mmolP]	0,3000	0,3000
Cation to P mole ratio in polyphosphate [meq/mmolP]	0,1500	0,1500
Ca to P mole ratio in polyphosphate [mmolCa/mmolP]	0,0500	0,0500

Propionic acetogenic

Name	Default	Value
Yield [-]	0,1000	0,1000
H2 yield [-]	0,4000	0,4000
CO2 yield [-]	1,0000	1,0000
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Methanogenic

Name	Default	Value
Acetoclastic yield [-]	0,1000	0,1000
Acetoclastic yield on methanol[-]	0,1000	0,1000
H2-utilizing yield [-]	0,1000	0,1000
H2-utilizing yield on methanol [-]	0,1000	0,1000
N in acetoclastic biomass [mgN/mgCOD]	0,0700	0,0700
N in H2-utilizing biomass [mgN/mgCOD]	0,0700	0,0700
P in acetoclastic biomass [mgP/mgCOD]	0,0220	0,0220
P in H2-utilizing biomass [mgP/mgCOD]	0,0220	0,0220
Acetoclastic fraction to endog. residue [-]	0,0800	0,0800
H2-utilizing fraction to endog. residue [-]	0,0800	0,0800
Acetoclastic COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200
H2-utilizing COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Sulfur oxidizing

Name	Default	Value
Yield (aerobic) [mgCOD/mgS]	0,5000	0,5000
Yield (Anoxic) [mgCOD/mgS]	0,3500	0,3500
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

Name	Default	Value
Yield [mgCOD/mg H2 COD]	0,0712	0,0712
Yield [mgCOD/mg Ac COD]	0,0470	0,0470
Yield [mgCOD/mg Pr COD]	0,0384	0,0384
N in biomass [mgN/mgCOD]	0,0700	0,0700
P in biomass [mgP/mgCOD]	0,0220	0,0220
Fraction to endogenous residue [-]	0,0800	0,0800
COD:VSS ratio [mgCOD/mgVSS]	1,4200	1,4200

General

Name	Default	Value
Tank head loss per metre of length (from flow) [m/m]	2,500E-3	2,500E-3
BOD calculation rate constant for Xsc degradation [/d]	0,5000	0,2721
BOD calculation rate constant for Xsp (and hydrocarbon) degradation [/d]	0,5000	0,2605
BOD calculation rate constant for Xeo degradation [/d]	0,5000	0,5000

Heating fuel/Chemical Costs

Name	Default	Value
Methanol [€/L]	0,3884	0,3884
Ferric chloride [€/kg Fe]	1,0327	1,0327
Ferric sulfate [€/kg Fe]	0,6973	0,6973
Ferrous chloride [€/kg Fe]	0,5384	0,5384

Ferrous sulfate [€/kg Fe]	2,0919	2,0919
Aluminum sulfate [€/kg Al]	1,4917	1,4917
Aluminum chloride [€/kg Al]	1,7477	1,7477
Poly Aluminum Chloride (PAC) [€/kg Al]	1,0327	1,0327
Natural gas [€/GJ]	2,6480	2,6480
Heating oil [€/L]	0,4413	0,4413
Diesel [€/L]	0,6179	0,6179
Custom fuel [€/L]	0,8827	0,8827
Biogas sale price [€/GJ]	1,7653	1,7653

Anaerobic digester

Name	Default	Value
Bubble rise velocity (anaerobic digester) [cm/s]	23,9000	23,9000
Bubble Sauter mean diameter (anaerobic digester) [cm]	0,3500	0,3500
Anaerobic digester gas hold-up factor []	1,0000	1,0000

Combined Heat and Power (CHP) engine

Name	Default	Value
Methane heat of combustion [kJ/mole]	800,0000	800,0000
Hydrogen heat of combustion [kJ/mole]	240,0000	240,0000
CHP engine heat price [€/kWh]	0	0
CHP engine power price [€/kWh]	0,1324	0,1324

Calorific values of heating fuels

Name	Default	Value
Calorific value of natural gas [kJ/kg]	48000	48000
Calorific value of heating fuel oil [kJ/kg]	42000	42000
Calorific value of diesel [kJ/kg]	46000	46000
Calorific value of custom fuel [kJ/kg]	32000	32000

Density of liquid heating fuels

Name	Default	Value
Density of heating fuel oil [kg/m3]	900	900
Density of diesel [kg/m3]	875	875
Density of custom fuel [kg/m3]	790	790

Mass transfer

Name	Default	Value	
Kl for H2 [m/d]	17,0000	17,0000	1,0240
Kl for CO2 [m/d]	10,0000	10,0000	1,0240
Kl for NH3 [m/d]	1,0000	1,0000	1,0240
Kl for CH4 [m/d]	8,0000	8,0000	1,0240
Kl for N2 [m/d]	15,0000	15,0000	1,0240
Kl for N2O [m/d]	8,0000	8,0000	1,0240
Kl for H2S [m/d]	1,0000	1,0000	1,0240
Kl for Ind #1 COD [m/d]	0	0	1,0240
Kl for Ind #2 COD [m/d]	0,5000	0,5000	1,0240
Kl for Ind #3 COD [m/d]	0	0	1,0240
Kl for O2 [m/d]	13,0000	13,0000	1,0240

Henry's law constants

Name	Default	Value	
CO2 [M/atm]	3,4000E-2	3,4000E-2	2400,0000
O2 [M/atm]	1,3000E-3	1,3000E-3	1500,0000
N2 [M/atm]	6,5000E-4	6,5000E-4	1300,0000
N2O [M/atm]	2,5000E-2	2,5000E-2	2600,0000
NH3 [M/atm]	5,8000E+1	5,8000E+1	4100,0000
CH4 [M/atm]	1,4000E-3	1,4000E-3	1600,0000
H2 [M/atm]	7,8000E-4	7,8000E-4	500,0000
H2S [M/Atm]	1,0000E-1	1,0000E-1	2200,0000
Ind 1 [M/Atm]	1,9000E+3	1,9000E+3	7300,0000

Ind 2 [M/Atm]	1,8000E-1	1,8000E-1	2200,0000
Ind 3 [M/Atm]	1,5000E-1	1,5000E-1	1900,0000

Properties constants

Name	Default	Value
K in Viscosity = K e ^(Ea/RT) [Pa s]	6,849E-7	6,849E-7
Ea in Viscosity = K e ^(Ea/RT) [j/mol]	1,780E+4	1,780E+4
Y in ML Viscosity = H2O viscosity * (1+A*MLSS^Y) [-]	1,0000	1,0000
A in ML Viscosity = H2O viscosity * (1+A*MLSS^Y) [m3/g]	1,000E-7	1,000E-7
A in ML Density = H2O density + A*MLSS [(kg/m3)/(g/m3)]	3,248E-4	3,248E-4
A in Antoine equn. [T in K, P in Bar {NIST}]	5,2000	5,2000
B in Antoine equn. [T in K, P in Bar {NIST}]	1734,0000	1734,0000
C in Antoine equn. [T in K, P in Bar {NIST}]	-39,5000	-39,5000

Metal salt solution densities

Name	Default	Value
Ferric chloride solution density [kg/m3]	3820,0000	3820,0000
Ferric sulfate solution density [kg/m3]	4800,0000	4800,0000
Ferrous chloride solution density [kg/m3]	3160,0000	3160,0000
Ferrous sulfate solution density [kg/m3]	1150,0000	1150,0000
Aluminum sulfate solution density [kg/m3]	1950,0000	1950,0000
Aluminum chloride solution density [kg/m3]	2480,0000	2480,0000

Mineral precipitation rates

Mineral precipitation constants

Name	Default	Value
Vivianite solubility product [mol/L]^5	1,710E-36	1,710E-36
FeS solubility product [mol/L]^2	4,258E-4	4,258E-4
Struvite solubility product [mol/L]^3	6,918E-14	6,918E-14
Brushite solubility product [mol/L]^2	2,490E-7	2,490E-7

Fe rates

Name	Default	Value	
A in aging rate = A * exp(-G/B) [1/d)]	16,1550	16,1550	1,0000
B in aging rate = A * exp(-G/B) [1/s)]	57,3000	57,3000	1,0000
HFO(L) aging rate factor	2,500E-4	2,500E-4	1,0000
HFO(H) with H2PO4- bound aging factor []	1,000E-5	1,000E-5	1,0000
HFO(L) with H2PO4- bound aging factor []	0,4000	0,4000	1,0000
H2PO4- coprecipitation rate [mol/(L d)]	1,500E-9	1,500E-9	1,0000
H2PO4- Adsorption rate [mol /(L d)]	2,000E-11	2,000E-11	1,0000
H+ competition for HFO(H) protonation sites [L/(mmol . d)]	1000,0000	1000,0000	1,0000
H+ competition for HFO(L) protonation sites [L/(mmol . d)]	100,0000	100,0000	1,0000

Fe constants

Name	Default	Value
Ferric active site factor(high) [{mol Sites}/{mol HFO(H)}]	4,0000	4,0000
Ferric active site factor(low) [{mol Sites}/{mol HFO(L)}]	2,4000	2,4000
H+ competition level for Fe(OH)3 [mol/L]	7,000E-7	7,000E-7
Equilibrium constant for FeOH3-H2PO4- [{mf HFO(H).H2PO4}/({mol H2PO4-}{mf HFO(H)}^2)]	2,000E-9	2,000E-9
Colloidal COD removed with Ferric [gCOD/Fe active site]	80,0000	80,0000
Minimum residual P level with iron addition [mgP/L]	0,0150	0,0150
HFO(H) with H2PO4- P release factor	10000,0000	10000,0000
HFO(L) with H2PO4- P release factor	10000,0000	10000,0000

Fe RedOx rates

Name	Default	Value	
Iron reduction using acetic acid	1,000E-7	1,000E-7	1,0000
Half Sat. acetic acid	0,5000	0,5000	1,0000
Iron reduction using propionic acid	1,000E-7	1,000E-7	1,0000
Half Sat. propionic acid	0,5000	0,5000	1,0000
Iron reduction using dissolved hydrogen gas	1,000E-7	1,000E-7	1,0000
Half Sat. dissolved hydrogen gas	0,5000	0,5000	1,0000

Iron reduction using hydrogen sulfide	5,000E-5	5,000E-5	1,0000
Half Sat. hydrogen sulfide	0,5000	0,5000	1,0000
Iron oxidation rate (aerobic)	1,000E-3	1,000E-3	1,0000
Abiotic iron reduction using acetic acid	2,000E-5	2,000E-5	1,0000
Abiotic iron reduction using propionic acid	2,000E-5	2,000E-5	1,0000
Abiotic iron reduction using dissolved hydrogen gas	2,000E-5	2,000E-5	1,0000
Abiotic iron reduction using hydrogen sulfide	2,000E-5	2,000E-5	1,0000
Abiotic iron oxidation rate (aerobic)	1,0000	1,0000	1,0000

CEPT rates

Name	Default	Value	
HFO colloidal adsorption rate	1,0000	1,0000	1,0000
Residual Xsc for adsorption to HFO	5,0000	5,0000	1,0000
Slope for Xsc residual	1,0000	1,0000	1,0000
HAO colloidal adsorption rate	1,0000	1,0000	1,0000
Residual Xsc for adsorption to HAO	5,0000	5,0000	1,0000
Slope for Xsc residual	1,0000	1,0000	1,0000

Al rates

Name	Default	Value	
A in aging rate = A * exp(-G/B) [1/d)]	16,1550	16,1550	1,0000
B in aging rate = A * exp(-G/B) [1/s)]	57,3000	57,3000	1,0000
HAO(L) aging rate factor	2,500E-4	2,500E-4	1,0000
HAO(H) with H2PO4- bound aging factor []	1,000E-5	1,000E-5	1,0000
HAO(L) with H2PO4- bound aging factor []	0,4000	0,4000	1,0000
H2PO4- coprecipitation rate [mol/(L d)]	1,500E-9	1,500E-9	1,0000
H2PO4- Adsorption rate [mol /(L d)]	1,000E-9	1,000E-9	1,0000

Al constants

Name	Default	Value
Al active site factor(high) [{mol Sites}/{mol HAO(H)}]	3,0000	3,0000

Al active site factor(low) [{mol Sites}/{mol HAO(L)}]	1,5000	1,5000
Equilibrium constant for AlOH3-H2PO4- [{mf HAO(H).H2PO4}/({mol H2PO4-}{mf HAO(H)}^2)]	8,000E-10	8,000E-10
Colloidal COD removed with Al [gCOD/Al active site]	30,0000	30,0000
Minimum residual P level with Al addition [mgP/L]	0,0150	0,0150
HAO(H) with H2PO4- P release factor	10000,0000	10000,0000
HAO(L) with H2PO4- P release factor	10000,0000	10000,0000

Pipe and pump parameters

Name	Default	Value
Static head [m]	0,2500	0,2500
Pipe length (headloss calc.s) [m]	50,0000	50,0000
Pipe inside diameter [mm]	500,000	500,000
K(fittings) - Total minor losses K	5,0000	5,0000
Pipe roughness [mm]	0,200	0,200
'A' in overall pump efficiency = A + B*Q + C*(Q^2)[-]	0,8500	0,8500
'B' in overall pump efficiency = A + B*Q + C*(Q^2)[[-]/(m3/d)]	0	0
'C' in overall pump efficiency = A + B*Q + C*(Q^2)[[-]/(m3/d)^2]	0	0

Fittings and loss coefficients ('K' values)

Name	Default	Value
Pipe entrance (bellmouth)	0,0500	1,0000
90° bend	0,7500	5,0000
45° bend	0,3000	2,0000
Butterfly value (open)	0,3000	1,0000
Non-return value	1,0000	0
Outlet (bellmouth)	0,2000	1,0000

Aeration

Name	Default	Value
Surface pressure [kPa]	101,3250	101,3250
Fractional effective saturation depth (Fed) [-]	0,3250	0,3250

Supply gas CO2 content [vol. %]	0,0400	0,0400
Supply gas O2 [vol. %]	20,9500	20,9500
Off-gas CO2 [vol. %]	2,0000	2,0000
Off-gas O2 [vol. %]	18,8000	18,8000
Off-gas H2 [vol. %]	0	0
Off-gas NH3 [vol. %]	0	0
Off-gas CH4 [vol. %]	0	0
Off-gas N2O [vol. %]	0	0
Surface turbulence factor [-]	2,0000	2,0000
Set point controller gain []	1,0000	1,0000

MABR Membrane effective diffusivities

MABR Membrane transfer factors

Name	Default	Value	
O2 []	1,0000	1,0000	1,0000
N2 []	1,0000	1,0000	1,0000
CO2 []	1,0000	1,0000	1,0000
H2 []	1,0000	1,0000	1,0000
CH4 []	1,0000	1,0000	1,0000
NH3 []	1,0000	1,0000	1,0000
N2O []	1,0000	1,0000	1,0000
H2S []	1,0000	1,0000	1,0000
Ind 1 []	1,0000	1,0000	1,0000
Ind 2 []	1,0000	1,0000	1,0000
Ind 3 []	1,0000	1,0000	1,0000

Blower

Name	Default	Value
Intake filter pressure drop [kPa]	3,5000	3,5000
Pressure drop through distribution system (piping/valves) [kPa]	3,0000	3,0000

Adiabatic/polytropic compression exponent (1.4 for adiabatic)	1,4000	1,4000
'A' in blower efficiency = A + B*Qa + C*(Qa^2)[-]	0,7500	0,7500
'B' in blower efficiency = A + B*Qa + C*(Qa^2)[[-]/(m3/hr (20C, 1 atm))]	0	0
'C' in blower efficiency = A + B*Qa + C*(Qa^2)[[-]/(m3/hr (20C, 1 atm))^2]	0	0

Name	Default	Value
k1 in C = k1(PC)^0.25 + k2	1,2400	1,2400
k2 in C = k1(PC)^0.25 + k2	0,8960	0,8960
Y in Kla = C Usg ^ Y - Usg in [m3/(m2 d)]	0,8880	0,8880
Area of one diffuser [m2]	0,0410	0,0410
Diffuser mounting height [m]	0,2500	0,2500
Min. air flow rate per diffuser m3/hr (20C, 1 atm)	0,5000	0,5000
Max. air flow rate per diffuser m3/hr (20C, 1 atm)	10,0000	10,0000
'A' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2 [kPa]	3,0000	3,0000
'B' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2[kPa/(m3/hr (20C, 1 atm))]	0	0
'C' in diffuser pressure drop = A + B*(Qa/Diff) + C*(Qa/Diff)^2[kPa/(m3/hr (20C, 1 atm))^2]	0	0

Surface aerators

Name	Default	Value
Surface aerator Std. oxygen transfer rate [kg O /(kW hr)]	1,50000	1,50000

Modified Vesilind

Name	Default	Value
Maximum Vesilind settling velocity (Vo) [m/d]	170,000	170,000
Vesilind hindered zone settling parameter (K) [L/g]	0,370	0,370
Clarification switching function [mg/L]	100,000	100,000
Specified TSS conc.for height calc. [mg/L]	2500,000	2500,000
Maximum compactability constant [mg/L]	15000,000	15000,000
Maximum compactability slope [L/mg]	0,010	0,010

Double exponential

Name	Default	Value
Maximum Vesilind settling velocity (Vo) [m/d]	410,000	410,000
Maximum (practical) settling velocity (Vo') [m/d]	270,000	270,000
Hindered zone settling parameter (Kh) [L/g]	0,400	0,400
Flocculent zone settling parameter (Kf) [L/g]	2,500	2,500
Maximum non-settleable TSS [mg/L]	20,0000	20,0000
Non-settleable fraction [-]	1,000E-3	1,000E-3
Specified TSS conc. for height calc. [mg/L]	2500,0000	2500,0000

Emission factors

Name	Default	Value
Carbon dioxide equivalence of nitrous oxide	296,0000	296,0000
Carbon dioxide equivalence of methane	23,0000	23,0000

Biofilm general

Name	Default	Value	
Attachment rate [g / (m2 d)]	8,0000	8,0000	1,0000
Attachment TSS half sat. [mg/L]	100,0000	100,0000	1,0000
Detachment rate [g/(m3 d)]	8000,0000	8000,0000	1,0000
Solids movement factor []	10,0000	10,0000	1,0000
Diffusion neta []	0,8000	0,8000	1,0000
Thin film limit [mm]	0,5000	0,5000	1,0000
Thick film limit [mm]	3,0000	3,0000	1,0000
Assumed Film thickness for tank volume correction (temp independent) [mm]	1,2500	1,2500	1,0000
Film surface area to media area ratio - Max.[ ]	1,0000	1,0000	1,0000
Minimum biofilm conc. for streamer formation [gTSS/m2]	4,0000	4,0000	1,0000

Maximum biofilm concentrations [mg/L]

Name	Default	Value	
Biomass - Ordinary heterotrophic	5,000E+4	5,000E+4	1,0000
Biomass - Methylotrophic	5,000E+4	5,000E+4	1,0000

Biomass - Ammonia oxidizing	1,000E+5	1,000E+5	1,0000
Biomass - Nitrite oxidizing	1,000E+5	1,000E+5	1,0000
Biomass - Anaerobic ammonia oxidizing	5,000E+4	5,000E+4	1,0000
Biomass - Phosphorus accumulating	5,000E+4	5,000E+4	1,0000
Biomass - Propionic acetogenic	5,000E+4	5,000E+4	1,0000
Biomass - Acetoclastic methanogenic	5,000E+4	5,000E+4	1,0000
Biomass - Hydrogenotrophic methanogenic	5,000E+4	5,000E+4	1,0000
Biomass - Endogenous products	3,000E+4	3,000E+4	1,0000
CODp - Slowly degradable particulate	5000,0000	5000,0000	1,0000
CODp - Slowly degradable colloidal	4000,0000	4000,0000	1,0000
CODp - Degradable external organics	5000,0000	5000,0000	1,0000
CODp - Undegradable non-cellulose	5000,0000	5000,0000	1,0000
CODp - Undegradable cellulose	5000,0000	5000,0000	1,0000
N - Particulate degradable organic	0	0	1,0000
P - Particulate degradable organic	0	0	1,0000
N - Particulate degradable external organics	0	0	1,0000
P - Particulate degradable external organics	0	0	1,0000
N - Particulate undegradable	0	0	1,0000
P - Particulate undegradable	0	0	1,0000
CODp - Stored PHA	5000,0000	5000,0000	1,0000
P - Releasable stored polyP	1,150E+6	1,150E+6	1,0000
P - Unreleasable stored polyP	1,150E+6	1,150E+6	1,0000
CODs - Complex readily degradable	0	0	1,0000
CODs - Acetate	0	0	1,0000
CODs - Propionate	0	0	1,0000
CODs - Methanol	0	0	1,0000
Gas - Dissolved hydrogen	0	0	1,0000
Gas - Dissolved methane	0	0	1,0000
N - Ammonia	0	0	1,0000
N - Soluble degradable organic	0	0	1,0000
Gas - Dissolved nitrous oxide	0	0	1,0000

N - Nitrite	0	0	1,0000
N - Nitrate	0	0	1,0000
Gas - Dissolved nitrogen	0	0	1,0000
P - Soluble phosphate	0	0	1,0000
CODs - Undegradable	0	0	1,0000
N - Soluble undegradable organic	0	0	1,0000
Influent inorganic suspended solids	1,300E+6	1,300E+6	1,0000
Precipitate - Struvite	8,500E+5	8,500E+5	1,0000
Precipitate - Brushite	1,165E+6	1,165E+6	1,0000
Precipitate - Hydroxy - apatite	1,600E+6	1,600E+6	1,0000
Precipitate - Vivianite	1,340E+6	1,340E+6	1,0000
HFO - High surface	5,000E+4	5,000E+4	1,0000
HFO - Low surface	5,000E+4	5,000E+4	1,0000
HFO - High with H2PO4- adsorbed	5,000E+4	5,000E+4	1,0000
HFO - Low with H2PO4- adsorbed	5,000E+4	5,000E+4	1,0000
HFO - Aged	5,000E+4	5,000E+4	1,0000
HFO - Low with H+ adsorbed	5,000E+4	5,000E+4	1,0000
HFO - High with H+ adsorbed	5,000E+4	5,000E+4	1,0000
HAO - High surface	5,000E+4	5,000E+4	1,0000
HAO - Low surface	5,000E+4	5,000E+4	1,0000
HAO - High with H2PO4- adsorbed	5,000E+4	5,000E+4	1,0000
HAO - Low with H2PO4- adsorbed	5,000E+4	5,000E+4	1,0000
HAO - Aged	5,000E+4	5,000E+4	1,0000
P - Bound on aged HMO	5,000E+4	5,000E+4	1,0000
Metal soluble - Magnesium	0	0	1,0000
Metal soluble - Calcium	0	0	1,0000
Metal soluble - Ferric	0	0	1,0000
Metal soluble - Ferrous	0	0	1,0000
Metal soluble - Aluminum	0	0	1,0000
Other Cations (strong bases)	0	0	1,0000
Other Anions (strong acids)	0	0	1,0000

Gas - Dissolved total CO2	0	0	1,0000
User defined - UD1	0	0	1,0000
User defined - UD2	0	0	1,0000
User defined - UD3	5,000E+4	5,000E+4	1,0000
User defined - UD4	5,000E+4	5,000E+4	1,0000
Biomass - Sulfur oxidizing	1,000E+5	1,000E+5	1,0000
Biomass - Sulfur reducing propionic acetogenic	5,000E+4	5,000E+4	1,0000
Biomass - Sulfur reducing acetotrophic	5,000E+4	5,000E+4	1,0000
Biomass - Sulfur reducing hydrogenotrophic	1,000E+5	1,000E+5	1,0000
Gas - Dissolved total sulfides	0	0	1,0000
S - Soluble sulfate	0	0	1,0000
S - Particulate elemental sulfur	5,000E+4	5,000E+4	1,0000
Precipitate - Ferrous sulfide	5,000E+4	5,000E+4	1,0000
CODp - Adsorbed hydrocarbon	5,000E+4	5,000E+4	1,0000
CODs - Degradable volatile ind. #1	0	0	1,0000
CODs - Degradable volatile ind. #2	0	0	1,0000
CODs - Degradable volatile ind. #3	0	0	1,0000
CODs - Soluble hydrocarbon	0	0	1,0000
Gas - Dissolved oxygen	0	0	1,0000

Effective diffusivities [m2/s]

Name	Default	Value	
Biomass - Ordinary heterotrophic	5,000E-14	5,000E-14	1,0290
Biomass - Methylotrophic	5,000E-14	5,000E-14	1,0290
Biomass - Ammonia oxidizing	5,000E-14	5,000E-14	1,0290
Biomass - Nitrite oxidizing	5,000E-14	5,000E-14	1,0290
Biomass - Anaerobic ammonia oxidizing	5,000E-14	5,000E-14	1,0290
Biomass - Phosphorus accumulating	5,000E-14	5,000E-14	1,0290
Biomass - Propionic acetogenic	5,000E-14	5,000E-14	1,0290
Biomass - Acetoclastic methanogenic	5,000E-14	5,000E-14	1,0290
Biomass - Hydrogenotrophic methanogenic	5,000E-14	5,000E-14	1,0290

Biomass - Endogenous products	5,000E-14	5,000E-14	1,0290
CODp - Slowly degradable particulate	5,000E-14	5,000E-14	1,0290
CODp - Slowly degradable colloidal	5,000E-10	5,000E-10	1,0290
CODp - Degradable external organics	5,000E-14	5,000E-14	1,0290
CODp - Undegradable non-cellulose	5,000E-14	5,000E-14	1,0290
CODp - Undegradable cellulose	5,000E-14	5,000E-14	1,0290
N - Particulate degradable organic	5,000E-14	5,000E-14	1,0290
P - Particulate degradable organic	5,000E-14	5,000E-14	1,0290
N - Particulate degradable external organics	5,000E-14	5,000E-14	1,0290
P - Particulate degradable external organics	5,000E-14	5,000E-14	1,0290
N - Particulate undegradable	5,000E-14	5,000E-14	1,0290
P - Particulate undegradable	5,000E-14	5,000E-14	1,0290
CODp - Stored PHA	5,000E-14	5,000E-14	1,0290
P - Releasable stored polyP	5,000E-14	5,000E-14	1,0290
P - Unreleasable stored polyP	5,000E-14	5,000E-14	1,0290
CODs - Complex readily degradable	6,900E-10	6,900E-10	1,0290
CODs - Acetate	1,240E-9	1,240E-9	1,0290
CODs - Propionate	8,300E-10	8,300E-10	1,0290
CODs - Methanol	1,600E-9	1,600E-9	1,0290
Gas - Dissolved hydrogen	5,850E-9	5,850E-9	1,0290
Gas - Dissolved methane	1,963E-9	1,963E-9	1,0290
N - Ammonia	2,000E-9	2,000E-9	1,0290
N - Soluble degradable organic	1,370E-9	1,370E-9	1,0290
Gas - Dissolved nitrous oxide	1,607E-9	1,607E-9	1,0290
N - Nitrite	2,980E-9	2,980E-9	1,0290
N - Nitrate	2,980E-9	2,980E-9	1,0290
Gas - Dissolved nitrogen	1,900E-9	1,900E-9	1,0290
P - Soluble phosphate	2,000E-9	2,000E-9	1,0290
CODs - Undegradable	6,900E-10	6,900E-10	1,0290
N - Soluble undegradable organic	6,850E-10	6,850E-10	1,0290
Influent inorganic suspended solids	5,000E-14	5,000E-14	1,0290

Precipitate - Struvite	5,000E-14	5,000E-14	1,0290
Precipitate - Brushite	5,000E-14	5,000E-14	1,0290
Precipitate - Hydroxy - apatite	5,000E-14	5,000E-14	1,0290
Precipitate - Vivianite	5,000E-14	5,000E-14	1,0290
HFO - High surface	5,000E-14	5,000E-14	1,0290
HFO - Low surface	5,000E-14	5,000E-14	1,0290
HFO - High with H2PO4- adsorbed	5,000E-14	5,000E-14	1,0290
HFO - Low with H2PO4- adsorbed	5,000E-14	5,000E-14	1,0290
HFO - Aged	5,000E-14	5,000E-14	1,0290
HFO - Low with H+ adsorbed	5,000E-14	5,000E-14	1,0290
HFO - High with H+ adsorbed	5,000E-14	5,000E-14	1,0290
HAO - High surface	5,000E-14	5,000E-14	1,0290
HAO - Low surface	5,000E-14	5,000E-14	1,0290
HAO - High with H2PO4- adsorbed	5,000E-14	5,000E-14	1,0290
HAO - Low with H2PO4- adsorbed	5,000E-14	5,000E-14	1,0290
HAO - Aged	5,000E-14	5,000E-14	1,0290
P - Bound on aged HMO	5,000E-14	5,000E-14	1,0290
Metal soluble - Magnesium	7,200E-10	7,200E-10	1,0290
Metal soluble - Calcium	7,200E-10	7,200E-10	1,0290
Metal soluble - Ferric	4,800E-10	4,800E-10	1,0290
Metal soluble - Ferrous	4,800E-10	4,800E-10	1,0290
Metal soluble - Aluminum	4,800E-10	4,800E-10	1,0290
Other Cations (strong bases)	1,440E-9	1,440E-9	1,0290
Other Anions (strong acids)	1,440E-9	1,440E-9	1,0290
Gas - Dissolved total CO2	1,960E-9	1,960E-9	1,0290
User defined - UD1	6,900E-10	6,900E-10	1,0290
User defined - UD2	6,900E-10	6,900E-10	1,0290
User defined - UD3	5,000E-14	5,000E-14	1,0290
User defined - UD4	5,000E-14	5,000E-14	1,0290
Biomass - Sulfur oxidizing	5,000E-14	5,000E-14	1,0290
Biomass - Sulfur reducing propionic acetogenic	5,000E-14	5,000E-14	1,0290

Biomass - Sulfur reducing acetotrophic	5,000E-14	5,000E-14	1,0290
Biomass - Sulfur reducing hydrogenotrophic	5,000E-14	5,000E-14	1,0290
Gas - Dissolved total sulfides	1,530E-9	1,530E-9	1,0290
S - Soluble sulfate	2,130E-10	2,130E-10	1,0290
S - Particulate elemental sulfur	5,000E-14	5,000E-14	1,0290
Precipitate - Ferrous sulfide	5,000E-14	5,000E-14	1,0290
CODp - Adsorbed hydrocarbon	5,000E-14	5,000E-14	1,0290
CODs - Degradable volatile ind. #1	7,240E-10	7,240E-10	1,0290
CODs - Degradable volatile ind. #2	8,900E-10	8,900E-10	1,0290
CODs - Degradable volatile ind. #3	7,960E-10	7,960E-10	1,0290
CODs - Soluble hydrocarbon	7,120E-10	7,120E-10	1,0290
Gas - Dissolved oxygen	2,500E-9	2,500E-9	1,0290

EPS Strength coefficients [ ]

Name	Default	Value	
Biomass - Ordinary heterotrophic	1,0000	1,0000	1,0000
Biomass - Methylotrophic	1,0000	1,0000	1,0000
Biomass - Ammonia oxidizing	5,0000	5,0000	1,0000
Biomass - Nitrite oxidizing	25,0000	25,0000	1,0000
Biomass - Anaerobic ammonia oxidizing	10,0000	10,0000	1,0000
Biomass - Phosphorus accumulating	1,0000	1,0000	1,0000
Biomass - Propionic acetogenic	1,0000	1,0000	1,0000
Biomass - Acetoclastic methanogenic	1,0000	1,0000	1,0000
Biomass - Hydrogenotrophic methanogenic	1,0000	1,0000	1,0000
Biomass - Endogenous products	1,0000	1,0000	1,0000
CODp - Slowly degradable particulate	1,0000	1,0000	1,0000
CODp - Slowly degradable colloidal	1,0000	1,0000	1,0000
CODp - Degradable external organics	1,0000	1,0000	1,0000
CODp - Undegradable non-cellulose	1,0000	1,0000	1,0000
CODp - Undegradable cellulose	1,0000	1,0000	1,0000
N - Particulate degradable organic	1,0000	1,0000	1,0000

P - Particulate degradable organic	1,0000	1,0000	1,0000
N - Particulate degradable external organics	1,0000	1,0000	1,0000
P - Particulate degradable external organics	1,0000	1,0000	1,0000
N - Particulate undegradable	1,0000	1,0000	1,0000
P - Particulate undegradable	1,0000	1,0000	1,0000
CODp - Stored PHA	1,0000	1,0000	1,0000
P - Releasable stored polyP	1,0000	1,0000	1,0000
P - Unreleasable stored polyP	1,0000	1,0000	1,0000
CODs - Complex readily degradable	0	0	1,0000
CODs - Acetate	0	0	1,0000
CODs - Propionate	0	0	1,0000
CODs - Methanol	0	0	1,0000
Gas - Dissolved hydrogen	0	0	1,0000
Gas - Dissolved methane	0	0	1,0000
N - Ammonia	0	0	1,0000
N - Soluble degradable organic	0	0	1,0000
Gas - Dissolved nitrous oxide	0	0	1,0000
N - Nitrite	0	0	1,0000
N - Nitrate	0	0	1,0000
Gas - Dissolved nitrogen	0	0	1,0000
P - Soluble phosphate	0	0	1,0000
CODs - Undegradable	0	0	1,0000
N - Soluble undegradable organic	0	0	1,0000
Influent inorganic suspended solids	0,3300	0,3300	1,0000
Precipitate - Struvite	1,0000	1,0000	1,0000
Precipitate - Brushite	1,0000	1,0000	1,0000
Precipitate - Hydroxy - apatite	1,0000	1,0000	1,0000
Precipitate - Vivianite	1,0000	1,0000	1,0000
HFO - High surface	1,0000	1,0000	1,0000
HFO - Low surface	1,0000	1,0000	1,0000
HFO - High with H2PO4- adsorbed	1,0000	1,0000	1,0000

HFO - Low with H2PO4- adsorbed	1,0000	1,0000	1,0000
HFO - Aged	1,0000	1,0000	1,0000
HFO - Low with H+ adsorbed	1,0000	1,0000	1,0000
HFO - High with H+ adsorbed	1,0000	1,0000	1,0000
HAO - High surface	1,0000	1,0000	1,0000
HAO - Low surface	1,0000	1,0000	1,0000
HAO - High with H2PO4- adsorbed	1,0000	1,0000	1,0000
HAO - Low with H2PO4- adsorbed	1,0000	1,0000	1,0000
HAO - Aged	1,0000	1,0000	1,0000
P - Bound on aged HMO	1,0000	1,0000	1,0000
Metal soluble - Magnesium	0	0	1,0000
Metal soluble - Calcium	0	0	1,0000
Metal soluble - Ferric	0	0	1,0000
Metal soluble - Ferrous	0	0	1,0000
Metal soluble - Aluminum	0	0	1,0000
Other Cations (strong bases)	0	0	1,0000
Other Anions (strong acids)	0	0	1,0000
Gas - Dissolved total CO2	0	0	1,0000
User defined - UD1	0	0	1,0000
User defined - UD2	0	0	1,0000
User defined - UD3	1,0000	1,0000	1,0000
User defined - UD4	1,0000	1,0000	1,0000
Biomass - Sulfur oxidizing	1,0000	1,0000	1,0000
Biomass - Sulfur reducing propionic acetogenic	1,0000	1,0000	1,0000
Biomass - Sulfur reducing acetotrophic	1,0000	1,0000	1,0000
Biomass - Sulfur reducing hydrogenotrophic	1,0000	1,0000	1,0000
Gas - Dissolved total sulfides	0	0	1,0000
S - Soluble sulfate	0	0	1,0000
S - Particulate elemental sulfur	1,0000	1,0000	1,0000
Precipitate - Ferrous sulfide	1,0000	1,0000	1,0000
CODp - Adsorbed hydrocarbon	1,0000	1,0000	1,0000

CODs - Degradable volatile ind. #1	0	0	1,0000
CODs - Degradable volatile ind. #2	0	0	1,0000
CODs - Degradable volatile ind. #3	0	0	1,0000
CODs - Soluble hydrocarbon	0	0	1,0000
Gas - Dissolved oxygen	0	0	1,0000