A Prototype Forecast-Informed Reservoir **Operation (FIRO) for Lake Conroe, TX**

- Application of NOAA/WPC's QPF and CPC's Outlooks in **Reservoir Operational Modeling**

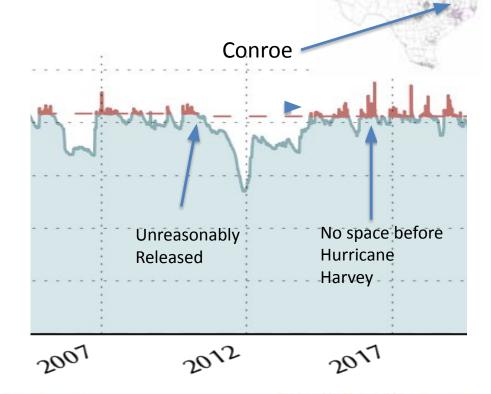
John Zhu, Ph.D., P.G. and Nelun Fernando, Ph.D.

Water Availability Program Surface Water Division

Background and Motivation

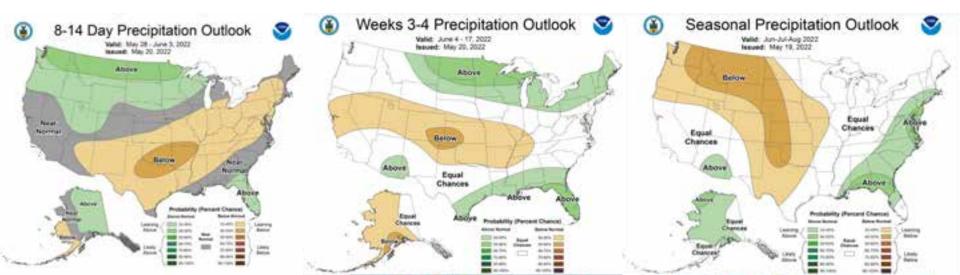
Forecast-informed reservoir operations
 (FIRO) is a reservoir-operations strategy that
 uses ... weather and water forecasts to
 inform decision making to selectively retain
 or release water from reservoirs to optimize
 water supply reliability and ... to enhance
 flood-risk reduction. (drought.gov)

 Lake Conroe is selected as the prototype because it is a water supply reservoir that must consider flood control operations, post Hurricane Harvey.

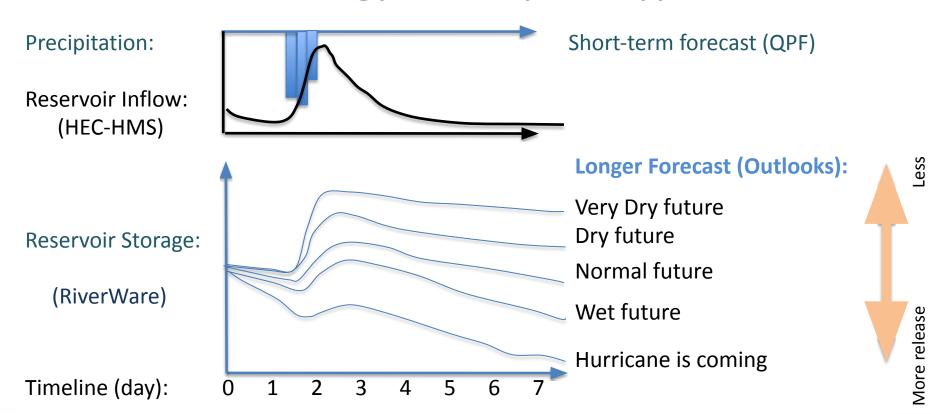


NOAA's Forecasts and Outlooks

 Quantitative Precipitation Forecast (QPF) for 7 days (6-hrs per file and total 28 grib2 files – retrieved by python scripts)
 https://www.wpc.ncep.noaa.gov/qpf/qpfloop_6hr_d17.html

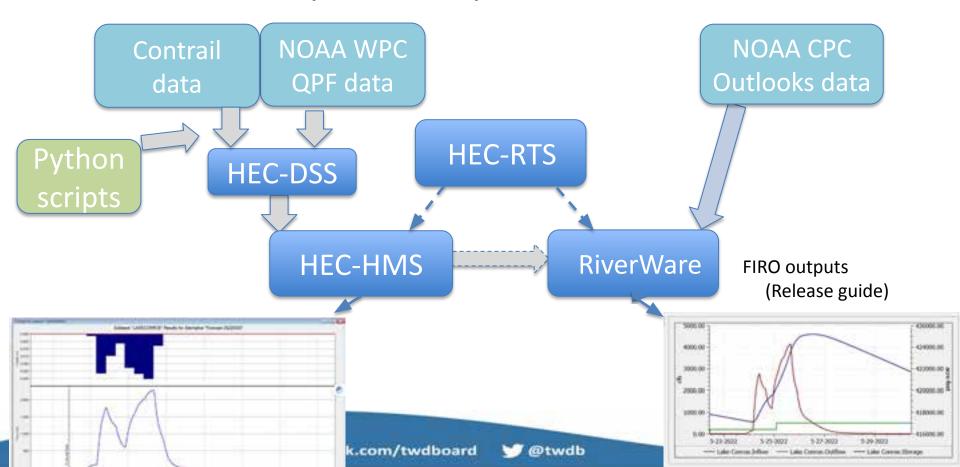


Methodology of our prototype FIRO



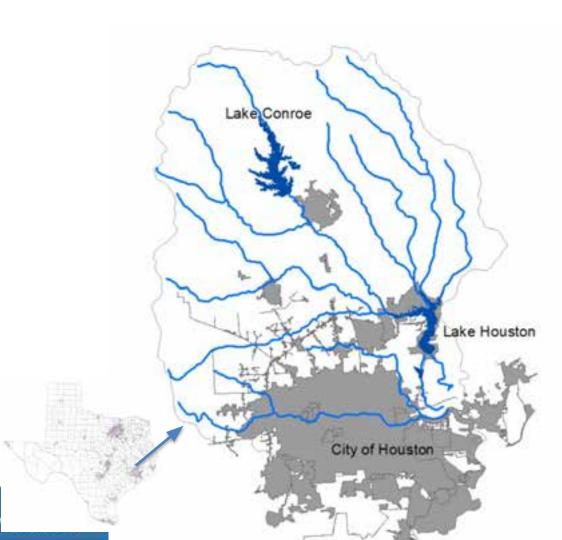
Not only is the short-term operation driven by short-term forecasts (QPF), but the operational target is also determined by the longer-lead forecast (various CPC Outlooks).

Data, toolsets, and workflow

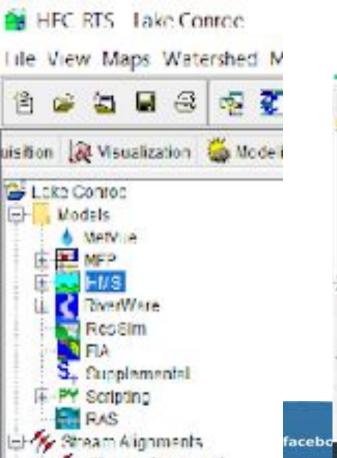


Lake Conroe

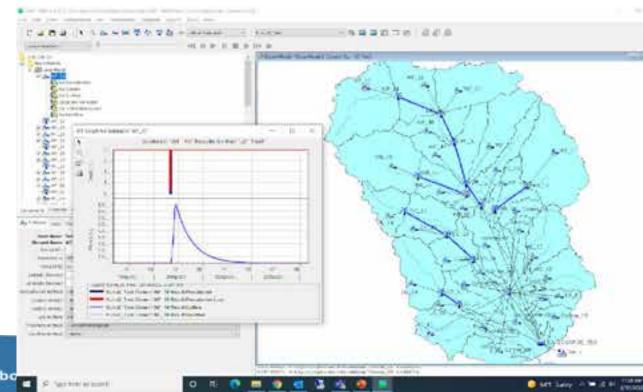
- Built in 1973; and jointly owned the San Jacinto River Authority (SJRA) and the City of Houston; it is operated by SJRA for water supply purpose.
- Added flood control operation after Hurricane Harvey.
- Total conservation capacity is 411,022 acre-feet at top of conservation pool at 201 feet msl.



HEC-RTS and **HEC-HMS** for Conroe watershed



HEC-HMS model for Lake Conroe Watershed



RiverWare model for Lake Conroe

Covering entire watershed 5 reaches, 1 reservoirs, 1 confluences, 6 diversions.

Use latest reservoir hydrographic survey - 2020 rating curve

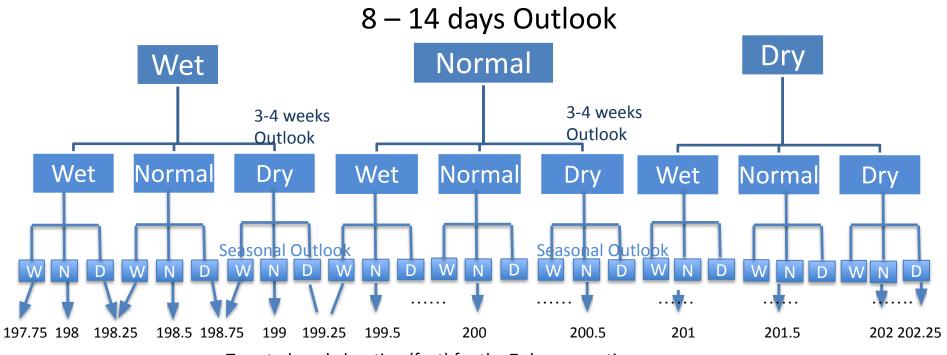
15-minute timestep



Contrail rainfall and QPF data fetching

- Past 24 hours rainfall data are retrieved through Contrail API.
- 6-hour NOAA-NWS-WFC Quantitative Precipitation Forecast (QPF) for next 7 days are downloaded into HEC-DSS.
- Data are disaggregated into 15-minute intervals to feed the HEC-HMS model.
- Past 24 hours streamflow at an upper stream of the lake is also retrieved for HEC-HMS model warming up.
- All done using python scripts.

Algorithm for determining operational target







Rule implementation in RiverWare model

Outher Rule (3)

Rules for Operational target:

Rules for release:

```
OperationalTarget
                                                                                                                                                                                                                                   1 3 Outline, Auto
                                                                                                                                                                                                                                   # (Little Comme : "Free! Streeture" | @"1 - 1" | in LACImentalitate : "Operational Target" | | ] THER
aluation Time: Beginning of run
                                                                                                                                                                                                                                        $" ( Lake Covine : "Find Elevation" [ GPL - 1" ] < 186.65 "R" ) Tright
                                                                                                                                                                                                                                            Lake Carrier . "Dudlow" | @'T" | + 6.00 "ofv"
   LkConroeData - "Precip814Dutlook" | > 8.00 AND LkConroeData - "P814Probability" | > 50.00 ) THEN
                                                                                                                                                                                                                                        BLSC P ( Latin Convex : "Facil Devention" [ 4"Y - 1"] ++ 196.00 "W AND Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention" [ 4"Y - 1"] + 196.00 "W" ( 196.00 Latin Convex : "Facil Devention"
  IF ( LKConroeData , "Precip34Coutlook" [] > 0.00 AND LKConroeData , "P30Probability" [] > 50.00 ) THEN
                                                                                                                                                                                                                                           Lake Conne . "Duffor" [ 9"1" ] = 200.00 '(f)"
                                                                                                                                                                                                                                        BLE P (Lake Corner - Tree December | GT - 1" ) to 188.50 W AND Lake Corner - Tree Humber [ GT - 1" ] + 199.50 W ) togs.
        F ( UcConroeData , "PrecipSeasonOutlook" [] > 0.00 AND UcConroeData , "PSeasonProbability" [] > 50.00 ] THEfti
                                                                                                                                                                                                                                           Lake Corese . "Duffort" | G'T' | + 550.36 "rft"
                                                                                                                                                                                                                                        H.SE F (Lake Corner, "Prof Devator" [4"1 : 1"] > + 180.00 W AND Lake Epison. "For Element" [4"1 : 1"] > 180.00 W Togs.
              197.75 "H"
                                                                                                                                                                                                                                           Lake Conroe . "Guffoot" [ @"Y" ] + £,809.50 "yV"
        ELSE # ( LkConroeData , "PrecipSeasonDutlook" [] < 0.00 AND LkConroeData , "PSeasonProbability" [] > 50.00 ] THEN
                                                                                                                                                                                                                                        BLSS # [ Lake Comme : "Not bleveller" [ $1 - 1" ] == 138.56 W ARE Lake Comme : "Not bleveller" [ $1 - 1" ] = 200.05 W ] Free
                                                                                                                                                                                                                                            Late Corese , "Outlier" | 9"T" | = 2,000.05 "vilv"
             198.25 "R"
                                                                                                                                                                                                                                       BLE F (Lake Cooks), "York Devictor" [ 6"1 : 1" ] == 200.00 W AND Lake Course. "Pool Devictor" [ 6"1 : 1" ] = 200.00 W ] Frein.
        ELSE
                                                                                                                                                                                                                                           late Corne . "Duffee" | @'T' | + LASCOT "M'
                                                                                                                                                                                                                                        ELM F (Lake Curron - Trail Showson* [47 - 1*] == 200.50 W AND Lake Curron - Trail Showson* [47 - 1*] + 201.00 W*) From
              198.00 "R"
                                                                                                                                                                                                                                            Lake Colonie . "Duffour" [ @"t" ] + 4,500.00 "cfu"
                                                                                                                                                                                                                                        ELSE F ( Lake Concer., "Faul Decembr" [ @"t - 1" ] >+ 30L00 "X" AND Lake Concer., "Faul Decembr" [ @"t - 1" ] + 30L00 "X" ) free.
        END IF
                                                                                                                                                                                                                                           Late Cerrie . "Duffeet" | @'Y' ] + 6.895.60 "ch/"
 ELSE IF ( LkCosroeData , "Precip34Ooutlook" [] < 0.00 AND LkConroeData , "P30Probability" [] > 50.00 ] THEN
                                                                                                                                                                                                                                        ELEC BY ( Lake Commis , "From Electron" [ 47] - 1" ] > - 201.55 MY AND Lake Commis , "From Electron" [ 47] - 1" ] < 202.65 M ) From
                                                                                                                                                                                                                                            Late Corece , "Outline" [ IST'] + 8,886,05 "ch";

▼ (LkConroeDate . "PrecipSemonOutlook" [] > 0.00 AND LkConroeDate . "PSeanonProbability" [] > 50.00 ] THEN

                                                                                                                                                                                                                                       $1.00 F (Life Corner, "Youl Decembe" [ $7" : 1" ] += 202.00 W Add Late Corner, "Youl Decembe" [ $7" : 2" ] + 202.00 W ) February
              198.75 "ft"
                                                                                                                                                                                                                                           Lake Course . "Duffour" [ @"] = 10,600.00 "chr"
                                                                                                                                                                                                                                        BLEE P ( Lake Convine , "Faul Structure" [ 8"1 - 1" ] >= 202.55 "W AND Line Convine. "Faul Structure" [ 8"1 - 1" ] + 202.65 "W" ) Tructs
        ELSE IF [LkConroeDate : "PrecipSeasonDutlook" [] < 0.00 AND LkConroeDate . "PSeasonProbability" [] > 50.00 ] THEN
                                                                                                                                                                                                                                            Lake Carrier - "Dolflow" [ $77 ] + 12,000-36 "MV
                                                                                                                                                                                                                                       BLES F ( Lake Contra, "Year Devature" [ 67 - 17 ] -- JULISS W AND LINE Extrem. "Year Strumber" [ 67 - 17 ] - JULISS W ] THEM
              199.25 "tt"
                                                                                                                                                                                                                                           Late Corne - "Durbou" [ @"f" ] + 18,800.86."65"
        BLSE
                                                                                                                                                                                                                                        ELECT ( Lake Correct, "Tool Develor" [ 4"] - 1"] - 255.50 "W. AID Line Energy, "You! Decision!" [ 4"] - 214.00 "F" ] Tright
                                                                                                                                                                                                                                           Late Corner , "Dufflow" [ @"T ] = 25L606.29. "GN"
              199:00 "ft"
                                                                                                                                                                                                                                        BLSE S (Late Curron : Youl Keroman" [ @T - 1" ] > + 304.06 TE AND Late Curron : Youl Herman" [ @T - 1" ] + 304.06 TE ) French
        END IF
                                                                                                                                                                                                                                           Lake Covroe , "Dutflow!" [ @"T" ] = 25,606.50 "cN"
                                                                                                                                                                                                                                        ELSE F (Lake Correct, "Prof December" [ 67 - 1" ] == 204.50 W AND Lake Correct, "You! December" [ 67 - 1" ] = 205.00 W".) Trips
  ELSE
                                                                                                                                                                                                                                            Lake Covers . "Duffor" | 6"Y" | = 36,800,56 "cfs"
        F ( LkConroeData : "PrecipSeasonOutlook" [] > 0.00 AND LkConroeData : "PSeasonProbability" [] > 50.00 ] THEN
                                                                                                                                                                                                                                       NUM S- ( Lake Commus . "Yout December" [ 671 - 17 ] = 200.00 "W" AND Like Commus . "Yout December" [ 671 - 17 ] = 200.00 "W" ) Trepts
                                                                                                                                                                                                                                           Late Corne : "Outloor" | 80"1" | + 25,016.00 "chi"
              198.75 "h"
                                                                                                                                                                                                                                        ELSE # (Late Connex . Youl Director) [ @7 - 1" ] >= 201.50 W AND Late Connex . Your Director [ @7 - 1" ] + 201.00 W) Triple
        ELSE # ( LkConroeData . "PrecipSeasonOutlook" [ ] < 0.00 AND LkConroeData . "PSeasonProbability" [ ] > 50.00 ) THEN
                                                                                                                                                                                                                                           Lake Connie . "Duffout" [ $77"] = 41,000,00 "oh!"
                                                                                                                                                                                                                                        R.SEP (Late Corres - 'Paul Decembr' [ $1' - 1' ] >= 200.36 TV AND Late Corres - 'Paul Recorder' [ $1' - 1' ] > 200.36 TV AND
              198.25 "ft"
                                                                                                                                                                                                                                           Late Covers . "Duchow" [ @"f" ] = 50,800.00 "cfc"
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Large storm (Hurricane) pre-release

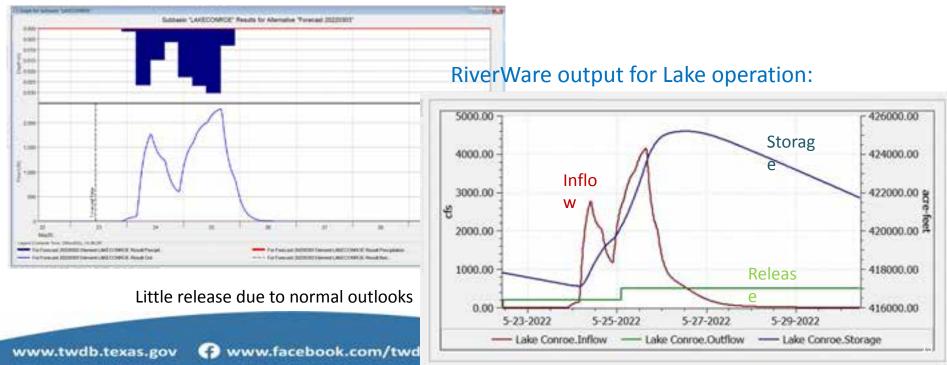
- Pre-release or lowering down pool elevation is determined by forecasted total inflow of the third day from current day.
- The release rate and lowering level depend on amount of forecasted total inflow.
- The release time is before the third day's peak time of the inflow.
- This pre-release operation is the highest priority (No.1 rule).

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# ( | formation | Test Day | Description | And Company | And Company | And Company | And Company | And Thomselve | And Thomsel
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Result of simulations (May 22-30, 2022)

Regular runs set every 7 days. Flood prevention runs set every 6 hrs or every day depending situation.

HEC-HMS output:



Key take aways

- NOAA's QPF and Outlooks can be used for reservoir operation by FIRO modeling. QPF Grib2 data can be automatically retrieved by python program.
- HEC-RTS, HEC-HMS and RiverWare can work together for this purpose.
- QPF appears reasonable, but it would the best for QPF in variable timesteps, 1-, 2-, 3-, and 6-hr for 0-6, 6-24, 24-48, 48-168 hours, respectively.
- More efforts are needed from the prototype to a formal/pilot model. (lake owner' data, other input data (i.e., HRRR), timesteps, model, calibration)

Questions?

Contacts:

John Zhu

(john.zhu@twdb.texas.gov)

Nelun Fernando

(nelun.fernando@twdb.texas.gov)





