My name is Terry Dawson and I've been the water accountant with the Bureau of Reclamation on the Fryingpan Arkansas transbasin diversion project for about a year now.

My goal in this talk isn't to let ya'll in on some groundbreaking work I'm doing. I don't think this is anything that I haven't seen in other people's models. But I haven't seen anyone else who is combining the rules with the forecasting and accounting in quite the same way. I'm hoping that if I let other people know what I'm doing I can find others who are doing the same thing and we can talk.

Let me tell ya'll a little about my project so you can get an idea of the kinds of challenges I'm facing as I try to bring our accounting methods into the 21st century.

Fryingpan Arkansas Project

This is an overview of my project. Each runoff season , we collect an average of 60,000 (meaning somewhere between 12,000 and 120,000) acre-feet of water in a diversion system on the west slope near Leadville.

Transmountain Diversion into Turquoise

I have a beautiful project

RECLAMATION

The water is collected and sent thru a transmountain tunnel to Turquoise Lake on the east slope. In addition there are several other tunnels and ditches that bring water to Turquoise for 5 account owners.

The water can be released down **either** a creek **or** through a hydroelectric plant to a conduit to Twin Lakes.

Some water is diverted for a fish hatchery and some native water is diverted into the conduit from creeks.

Mt Elbert and Twin Lakes

Isn't it gorgeous

FRYINGPAN-ARKANSAS PROJECT

RECLAMATION

In addition to the flow into Twin Lakes from Turquoise, there's another transmountain diversion **and** native inflow. Once in Twin, water can be pumped back up to

Mt Elbert pumped storage hydropower plant, **or** released down a creek, **or** pumped to a pipeline that takes it out of the Arkansas basin.

We operate Turquoise, Mt Elbert Forebay and Twin Lakes as a single system for agriculture, municipalities, industry, recreation, power generation, and fish and wildlife. This includes enhanced rafting and fishery flows throughout the year.

The flows out of Twin and Turquoise enter the Arkansas River above Granite and are captured in Pueblo Reservoir.

Pueblo Reservoir

This is my drive in to work

This is where it gets really fun. We have 7 types of accounts- project, project carryover, short term, long term, winter, winter carryover and native.

Some owners have one type of water with an acre-foot in the account. Others can have 5 different accounts with 10s of thousands of acre-feet in each.

All have a separate contract with the BOR as well as decrees, findings, MOUs, MOAs, NEPA questionnaires, good neighbor agreements, handshake deals **et cetera** that affect each type of water in different ways.

Last time I checked, there were 152 different accounts to track. We also support a fish hatchery, recreation with the state and outlets for different municipalities.

Challenges

- **4 reservoirs**
- **2 power plants**
- **4 transmountain diversions**
- **5 pipelines out of the reservoirs**
- **2 fish hatcheries**
- **3 controlling entities (BOR, State, SECWCD)**
- **7 types of accounts**
- **Over 150 individual accounts**
- **Hundreds of decrees, stipulations, MOUs, MOAs, contracts, reports, handshake agreements etc**
- **1 new accountant**

RECLAMATION

So, I have quite a few things to keep in mind as I run through my daily accounting: multiple interdependent reservoirs, Transmountain diversions, native inflows, releases through pipelines and down existing creeks, power generation, fish hatcheries, recreation, fish and wildlife flows. I have 7 types of accounts, **over** 150 individual accounts, 40 feet of file drawers with **contracts, decrees, MOUs et cetera** and………… one new accountant. I answer to federal, state and local customers.

What we do now

- **Manipulate data from emails and spreadsheets**
  - We've moved out of the scissors and tape realm
- **Enter that into the Oracle FryArk Program**
  - 283 separate pieces of SQL coding, all of which interact
  - More than 50 undocumented tables
- **Black box does its magic**
  - Calculates inflow, outflow, evap, content
  - Minimal validation
- **Spits out a prefabricated report**

RECLAMATION

The person who had the job before me was one of the smartest people I've ever met. She could hold numbers in her head as if they were her children. She never forgot a decree date, she always knew exactly what was in the lakes. And she did it all with printed spreadsheets she--- cut up with scissors ----and ----taped---- together. Every time I tried to do that, I ended up with papercuts .

I need some sort of a model to lean on.

When I first started learning the FryArk system we had a very strong front end to enter the data into an Oracle database. It has menus to enter data and there were some routines that calculated things like a fixed transit loss or evaps on the system and on different accounts. It adds inflows and subtracts releases. But that's about it.

FryArk Program

- Not flexible (pro and con)
- Cannot put in rules
- Little customization for reports
- Need external viewers for data or graphs
- Cannot be used for anything else

RECLAMATION

That program that does one thing *very* well. It keeps track of the accounting. Not being flexible isn't necessarily a bad thing for an accounting program. We *want* it to do the same thing in the same way every day. We don't want me to be able to tweak it if I think the evap rate is a little high or if one of the account holders' needs a little extra water this month. But as more and more regulations come into play, as contracts are signed and new decrees are issued, it becomes easier for things to slip through the cracks.

I can't put conditions or warnings on any of the accounts. There's no If-Then logic inside the program. Right now we have to have to check everything we remember- minimum and maximum flows at a dozen different sites, who's in priority, which kinds of water were listed in the NEPA questionnaire for each account ……………

My predecessor could do that. She knew the entire project inside and out. But it took her 20 years to learn it and she retired as soon as she had it down.

My goal is to have all of this programmed in so that, when I leave, someone else can walk right into my job and take over.

Another short coming of the FryArk program is the reporting. You have a choice of a **print out** or a PDF of the **print out.** With as much data as we deal with every day, it's impossible to process it simply by text. I mean look at that- can you really pick meaningful trends out of a bunch of text like this? To get a clear view of what's going on across the system, we need charts, graphs, sortable reports and other representations to be able to understand what the data means.

The current program can do the accounting and that's it. It's a narrow look at what occurred in the past.

Requirements for alternative

- **Works with Oracle**
- **Can use rules**
- **Can be updated but not easily altered**
- **Both flexible and constrained**
- **Handles after the fact accounting and forecasts**
- **Can be used in a variety of situations**
- **Can handle a variety of inputs**

RECLAMATION

I need an alternative. I needed something that can handle a variety of inputs- including an excision of the process we use now,

that's both flexible and constrained,

that can be updated but not easily altered,

that works with Oracle,

that can use rules that are easily documented and updated,

that uses reporting and visualization tools and can be used in a variety of situations.

I need models that can do after the fact accounting as well as short and long term forecasts.

And I want a single base model that can do all of this so the models for various purposes don't get out of sync.

You can see this list is full of contradictions.

Why change to Riverware

- **Can still incorporate FryArk program guts**
- **Can use Oracle**
- **Want to put in rules**
- **Want to do what if**
- **Forecasts**
- **Backcasts**
- **Accounting**
- **Single base model for any research in the basin**

RECLAMATION

Why change to Riverware? The really most important thing is that I can put in rules. That's the whole point of using a model instead of staying where we were.

The other first most important requirement is that the model use Oracle. I need the data to be served out so our internal customers can get to the data as soon as it's available and can use that data in a variety of ways to suit their needs and **mostly**, I **need** them to be able to use it without calling me for help on a daily basis. I use APEX, to get the data out so anyone inside our firewall can use it without having to go through me to get to it. Since everything is in web pages, training to get to and use the data is minimal.

The last first most important thing is that I need it to be both flexible and very hard to change. I'm still discovering **contracts, decrees, MOUs et cetera**., that I didn't know about before and that I'm incorporating into the model. Some of the contracts change every year. But the accounting **HAS TO BE** consistent and it has to be **seen** as being consistent by everyone concerned. I need a way to separate the simulation and the accounting.

I also want this model to be useful for anyone doing modeling on the FryArk. If we have a base to work from, it'll be easier to compare different studies. And I need it to be easy to introduce different data sets for different models. After looking around, it was pretty clear Riverware was the only software that would handle all these conflicting needs.

With the help of Tom Stockton, I've been putting together a model to see how the levels of complexity can be managed in a single model and how many of the conflicting requirements can be handled before it all blows up.

Where to Calculate

- **Inside Oracle**
  - Everything that's downloaded through a DMI but not loaded back up with a DMI
    - Time Series Aggregations
    - Native Evaporations
    - Lag and Loss at initial inflow sites
- **Inside Riverware**
  - Accounting and hydrology outside of the initial inflows

RECLAMATION

One of the first decisions I needed to make after choosing Riverware was how much of the calculating I was going to let Riverware do. One of the most fundamental philosophies I have is **don't** let me do anything the computer can do better. I transpose numbers, get operations out of order and use old equations when I try to do anything myself so I take myself out of the loop when it comes to actual numbers.

So, there are 2 places I can do calculations **without** me doing calculations- inside the database or inside Riverware.

Tim Miller and Andrew Gilmore, the two proponents of Riverware that set me down this path, agree that doing as many of the **base** calculations inside the database as possible is the way to go.

What I mean by base is any calculations that have to do with the inputs to Riverware. I know Riverware can aggregate gage inputs over time, calculate the lag and loss to the initial inputs to the system and handle the initial evap calculations. It's very tempting to let it do that since it can. The problem with this is when someone else is calculating the same data outside of Riverware, we risk having two sets of calculations and two chances of mistakes.

My decision is that, if we can bring the data in through a DMI and we won't upload the data back through a DMI, we'll do the calculations inside Oracle.

When I started my model, I figured out I could go in one of two directions- I could just do after the fact accounting or I could do a full service kind of model.

The accounting alone is actually pretty easy in Riverware and it would cover everything I'm doing with my current setup. But in the end, that doesn't give me anything other than what I have right now.

The power behind using a Riverware model is the way I can keep track of everything outside of "this much water starts here- this much water stops here". That means having everything that affects the flows and storages in the model. If I'm doing that, I might as well go for a full hydrologic forecasting model with every stinking rule I come across.

I told David once that there's a direct tradeoff between ease of use and flexibility and Riverware was very *very* flexible. But the truth is Riverware is straight forward. It's the person writing the model who gets tangled up in the spaghetti. I had to make a decision as to how I was going to try to write the rules- as I ran across them, thru time as things were written, or top down from the initial inflows to the system.

If I didn't stop to think about it, I'd have just jumped in and started writing rules as I came across them. That would mean I wouldn't forget something when the next new shiny object came into view. But that would also mean the rules would tangle with each other all the way down- there's enough complexity in here that trying to untangle which rules are being influenced by which would make it very difficult to check. A chronological order would let me make sure I wasn't using a rule that had been superseded but I'd run into the conflicts coming from up and down the river and the same problem untangling them. What I decided on was to start at the top, write each rule for each inflow **and** reach as I went down then rigorously check the operations when I came to confluences- especially at storage points. I'm very subject to the "Ooo shiny" syndrome. It would be very easy for me to find a rule that needed to be put in the model but it's not in the right order for what I'm doing. I've been putting those rules in as I find them, at least in a minimal fashion, and leaving them turned off until I get to the reach where they're located.

Comment Boxes!!!
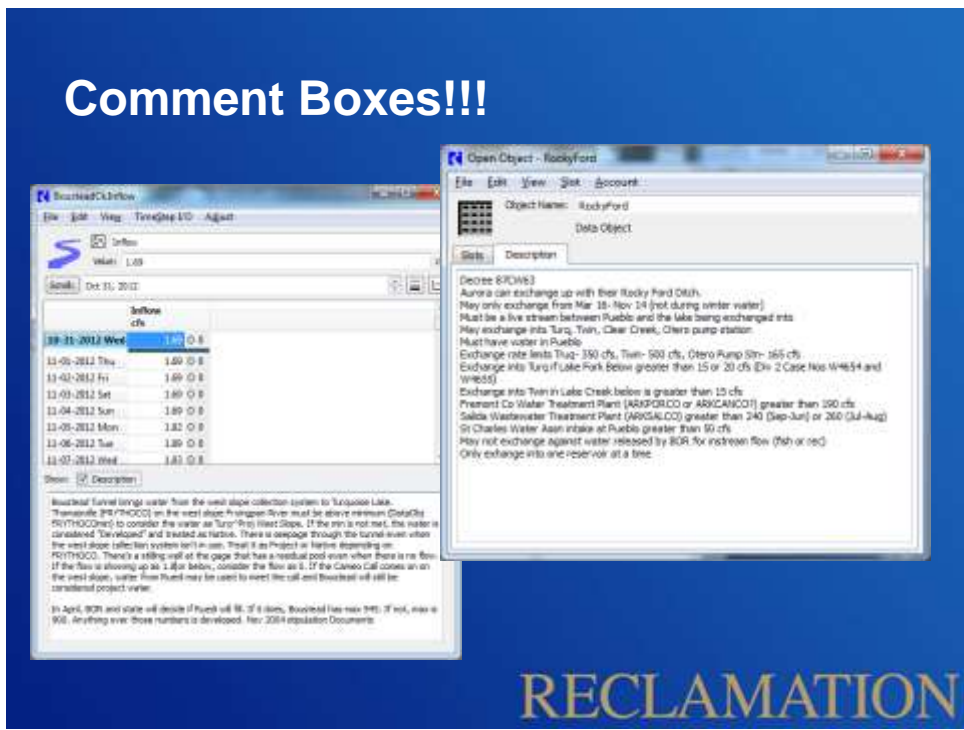
I'm also making as full as use as I can of comment boxes as I can. The Riverware report writer is wonderful but even if it weren't there, I would still be writing paragraphs documenting *everything* I could about each
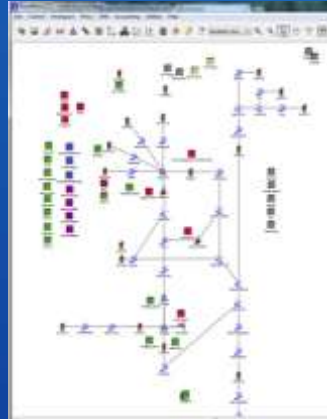
reach, rule, computation point, confluence, reservoir, gage.

That's one of the most valuable parts of Riverware for me. I can even upload documents into the Oracle database through APEX then put a url to the document inside the Riverware comment box. I can't tell you how wonderful it is to be able to grab the schematic then find out everything I need to know about a point, then move up and downstream to see if there are other things I need to know that would affect it. Even if I have to copy and paste the link to the original document scan, it's been the best way to organize the **contracts, decrees, MOUs et cetera**. that I've found so far. Being able to print off the reports with the comments is icing on the cake

If there's one thing I could get everyone to take away, it's to use the comment boxes fully. If you win the lottery and you're off to Tahiti, leave something behind for the person who gets hired to replace you so you don't have to take his phone calls while you're lying on the beach. It doesn't guide just the modeler but the spatial component is useful to regulatory and NEPA and contracting people or anyone else who is going to need to find out what they need to know about each point on the river system. And it's integrated into the model so the documentation can't get lost. And we do have a 20 year old model with no documentation so I know that can happen.
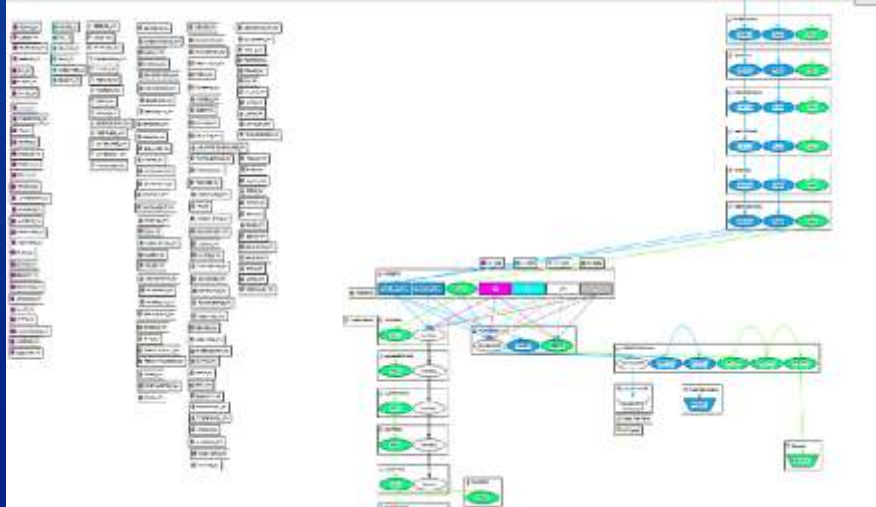
I'm very comfortable with the operations of my upper reservoirs. They're nicely behaved. The accounting works. The hydrology works. It makes me happy.

Pueblo Accounts

Now I'm working on the terminal storage reservoir at Pueblo. That's not nicely behaved. Well, it is hydrologically but there are about 150 accounts with 7 colors of water and more than 300 **contracts, decrees, MOUs et cetera**. I'm still deciding what the best way to handle this is.

Right now, I have the 7 colors of accounts set up inside the reservoir. Each individual account is broken out as a table. The tables interact with the riverware account.

I'm not doing it this way because the graphic would be impossible to read on the screen, although it would be. It's because, while each account has individual quirks, for the most part they boil down to 7 discrete sets of rules. It's been more efficient for me to deal with 7 "ACCOUNTS" and to consider the individual accounts as different hues of water.

I don't know for sure that I'll leave it this way. If anyone has advice, I'd love to hear it.

Testing

- **Run the historical record**
- **One year side by side**

Did I mention my river is pretty, too?

RECLAMATION

Once I'm satisfied with the accounting through Pueblo, I'm going to run the model side by side with my current accounting system for a year before I close down the old system. Experience has taught me that you can go back and run a model with data from the past 15 years on a daily basis and have the old and new models working perfectly in sync, but once you start moving ahead with day to day operations, something will glitch. Because the accounting MUST be right, I need to make sure, through all seasons, that we've got the exact same data coming out.

Well, not the exact same- there are a few places where I've found differences between what the current model should say and what it does say. They're mostly minor- differences in the thousandths for loss rates and such. But I'm still going to have to document those and talk to my account holders and the state before I replace the old system with the new.

And that brings me to my last point. No model, no matter how carefully it's checked, is perfect. There's always something that gets through the cracks. I'm preaching to the choir here, I know. But never never never forget that a model isn't reality. Cross check everything and never get complacent that it works right.

Any questions?