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The concept of linear scheduling



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THE CONCEPT OF LINEAR SCHEDULING

INTRODUCTION

Traditional scheduling software for the construction industry is dominated by Primavera, Microsoft Project, Power Project and others. All of these solutions provide opportunity to develop a series of activities that are logically connected to provide a sequence of events from project start to finish. While these tools are very powerful, they are designed for the construction of buildings and other facilities (power generating stations, refineries, etc.) and are not adequate for the constructability issues and demands of building a linear project such as a pipeline, rail system or roadway. The definition of a linear project is where a series of crews move, in sequence, along a ROW (right-of-way) during construction.

March charts (also known as Time-Distance charts) have been widely used in linear projects, particularly in Europe and the U.K. This methodology is newer to the Americas, but is rapidly gaining widespread acceptance. March charts are often hand drawn, prepared in Microsoft Excel or in a drawing program such as AutoCAD. Linear planning and scheduling software that automates the development of the plan and progressing is relatively recent (last 15 years or so). Key advantages of march charts are that the schedule are connected to the geography of the ROW and any constructability issues that are important to the project.

The intent of “The concept of linear scheduling” is to provide an overview of how to interpret and use march charts with an emphasis on using some of the linear planning software tools that are currently available. A list of software is provided at the end of this appendix.

THE BASICS

DIFFERENCES BETWEEN GANTT AND MARCH CHARTS

Gantt charts are familiar to anyone that has planned and scheduled a project. The planner creates a series of activities based on the project execution plan and then logically connects these activities (Finish-Start, Start-Start, Finish-Finish and Start-Finish). Resources can be added to each activity schedule and resource loading can be easily displayed. In order to maintain crew sequencing in a pipeline project the planner would make sure that each activity is connected to its successor by a Start-Start and a Finish-Finish relationship. A typical Gantt chart for a pipeline job is shown in Figure 1.

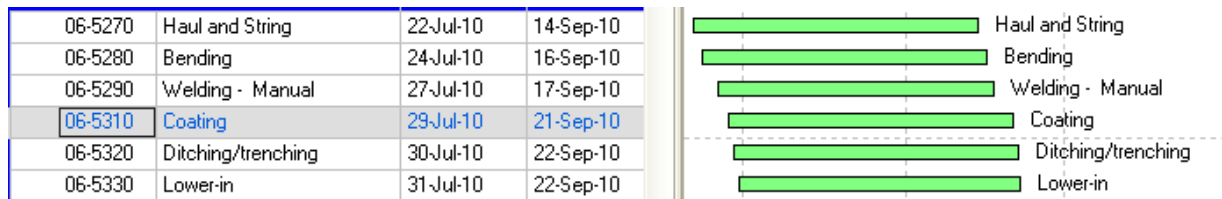


Figure 1 Traditional Gantt Chart

This Gantt charts clearly shows each activity with the start and end date of each activity. Any progress would be shown on the Gantt chart as the percent complete for each task. The problem with a traditional Gantt chart is that reporting that a bending crew is 45 % complete is quite meaningless because these traditional tools assume that progress is from start to finish and there is no connection between progress and the geography of the ROW. The ability to include crew moves, permitting delays, environmental restrictions and other construction issues is not possible.

A march chart on the other hand displays these same crews as a series of lines moving along the ROW. Each crew is logically connected to its successor with Start-Start and/or Finish-Finish relationships. Completed sections are easily identified with crew moves, crossings and environmental windows clearly visible on a march chart. Using same example, a march chart will clearly display **what** 45% of the ROW has been completed by the bending crew and how any moves or ROW access issues have impacted the progress.

A typical march chart (Figure 2) in its most basic form shows each crew represented by a different line type. Usually distance along the ROW is horizontal and increases from the left to the right. Time is typically represented vertically, increasing from bottom to top (although it can just as easily be shown increasing top to bottom). It should be noted that the orientation of the time and distance axes is a matter of personal preference and can easily be switched in the software.

The advantage of march charts is immediately obvious as you can easily determine the location of each crew at a particular point in time. Any issues associated with crew productivity rates are also readily apparent. For example, the red arrow in Figure 2 indicates that, based on the productivity of each crew, the lower-in crew will overtake the ditching crew between KP 25+000 and 30+000. This was not obvious in the Gantt chart view (Figure 1).

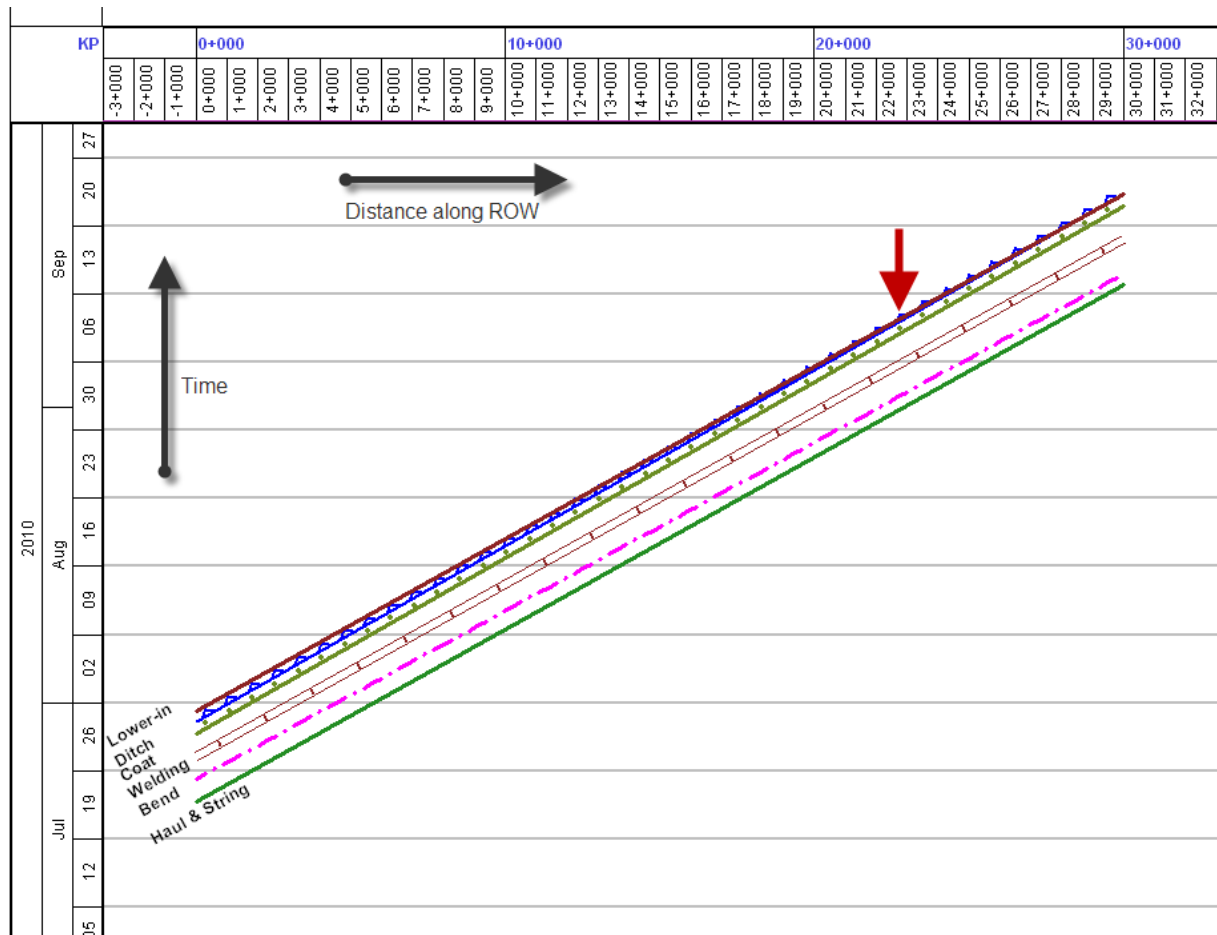


Figure 2 Simple March Chart

In a march chart the slope of the activity indicates the relative productivity rate for the crew. The steeper the slope, the slower the crew is moving (because more time is spent and less distance is completed). Non-work periods, such as scheduled days off or work stoppages appear as vertical segments on the crew line. A vertical line indicates that time is passing, but the crew is not moving. Figure 3 shows an example where the grade crew is moving slower (468 m/day) than the Haul and String crew (600m/day) with each crew working a 6 day 10h shift rotation. The green bars across the march chart, and the short vertical jumps in each crew, indicate the day off each week. This march chart shows that grading has to start about 18 days ahead of string in order to keep these crews from overlapping.

The productivity rates that are displayed are calculated automatically by the march chart software based on duration and length of each task.

For clarity and ease of explanation, all of the following examples in this guide will only show a few representative pipeline crews. Typically each crew is assigned to a different layer of the march chart so that the planner can display one or many crews simultaneously by activating the layers.

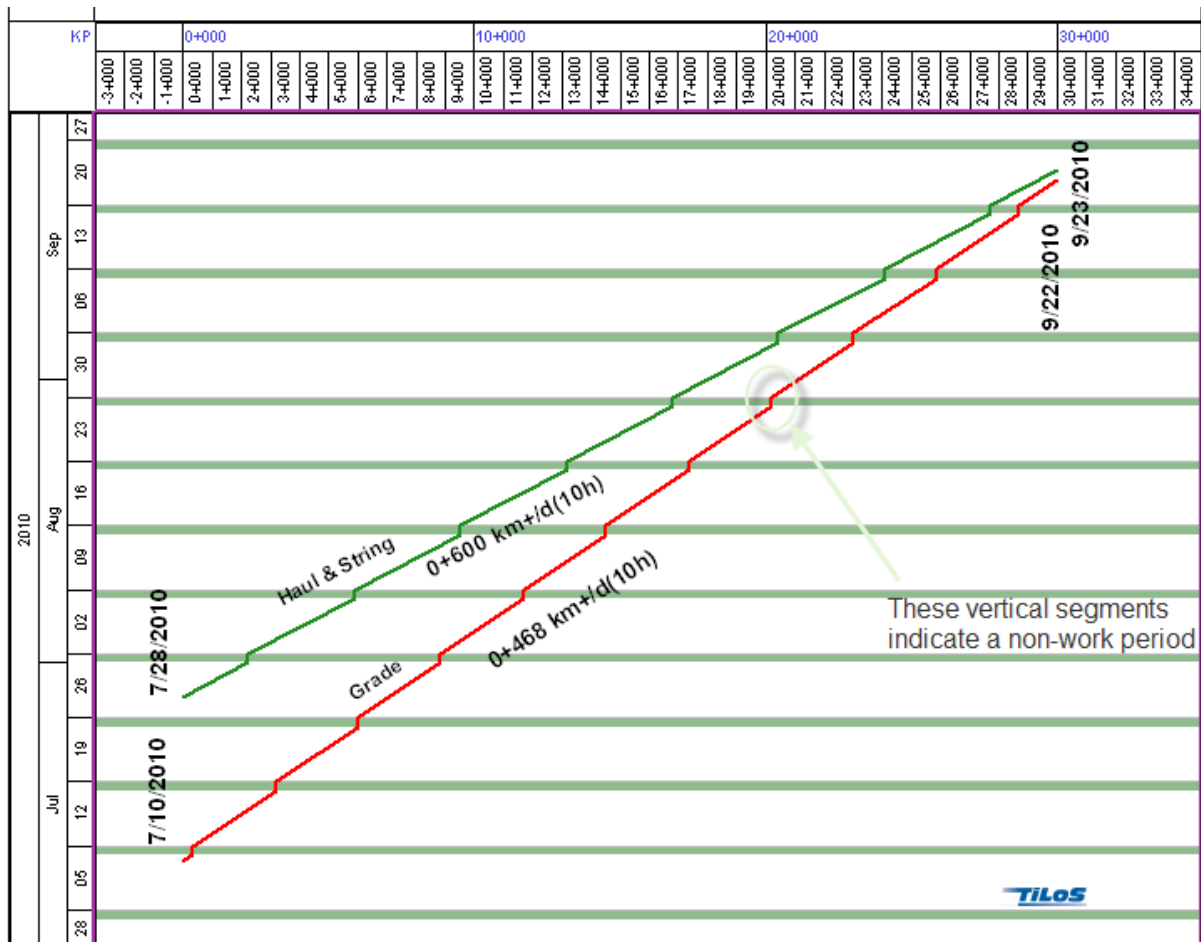


Figure 3 Productivity Rates and Slope

CONSTRUCTABILITY ISSUES

With a basic understanding of these march chart elements a march chart can be further enhanced to display any other critical elements of your project. These can include the ROW profile, crossings, environmental restrictions and land acquisitions. Other elements such as vegetation type, soil type and rainfall data can also be included on the march chart. The amount and type of information shown on a march chart is determined by the project team.

ROW PROFILE

The ROW profile is important in developing the hydro-test plan and to determine productivity rate changes based on elevation (discussed later in the section on speed profiles). Most profile data (LIDAR or survey) is available in a spreadsheet format and can be easily imported into a profile diagram using the import function of the march chart software to generate the ROW profile as seen below in Figure 4.

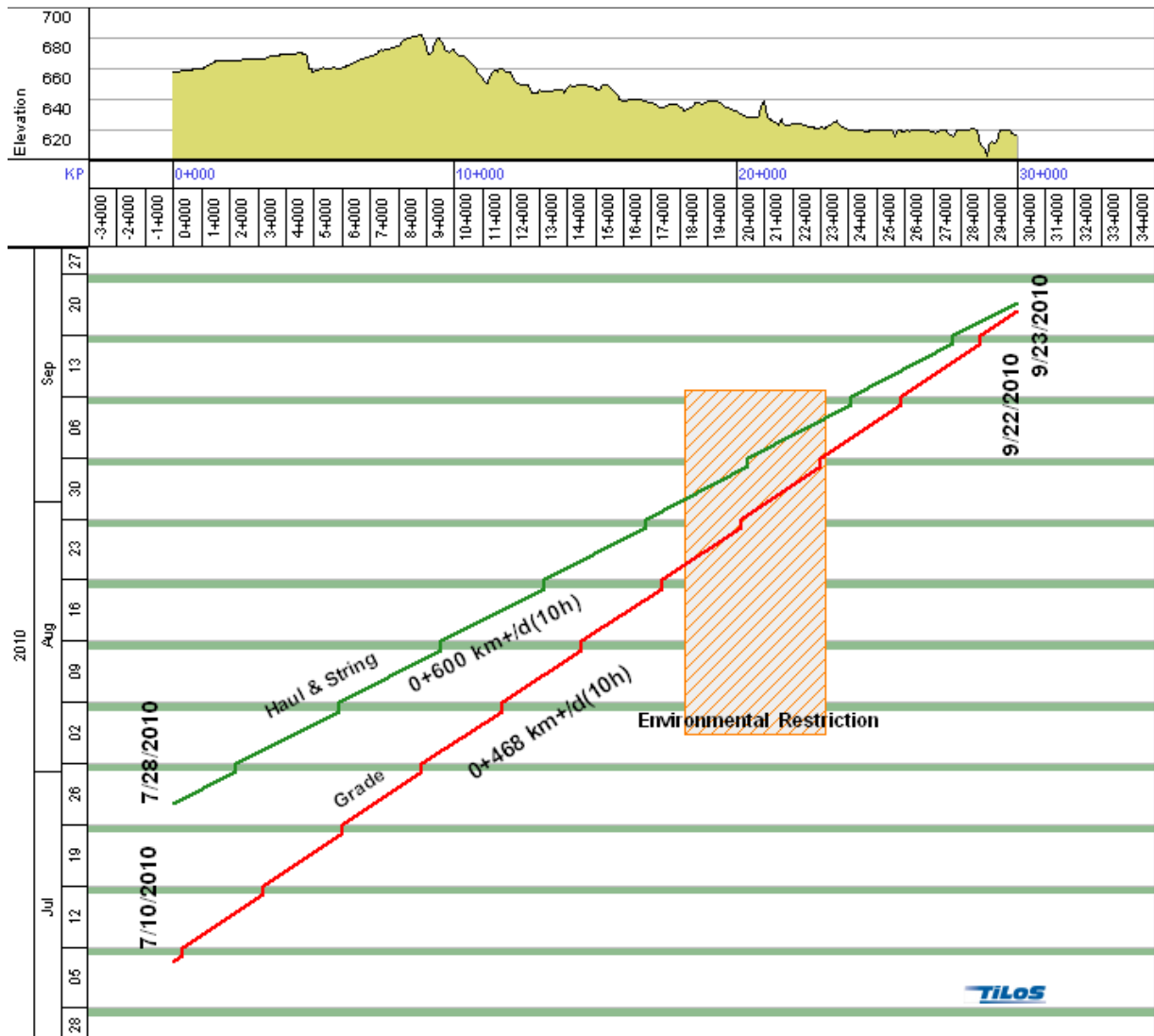


Figure 4 Elevation Profile and Restricted ROW Access

RESTRICTED ROW ACCESS

Construction of the pipeline may be hampered by periods when certain parts of the ROW are not accessible. This would include environmental windows for wildlife and rare plants, permitting issues or ROW acquisition delays.

Restricted access periods are easily represented graphically on a march chart by rectangular shapes as shown in Figure 5. Once the impact of a restriction has been evaluated it may be necessary to modify the work plan to avoid working in the restricted area. This can be done by splitting the crews so that the work that is impacted by the restricted area will be completed at a later date once the restricted period is over. Figure 5 illustrated a move for both the grade and string crew to avoid the restricted area. In this example, both crews skip the restricted area (1 day lag to allow for move) and continue to the end of the ROW at 30+000. Once this work is finished, and the environmental restriction has expired, both crews move back to the restricted area and complete it in a reverse lay. The red dashed lines indicate the logical links between each crew segment.

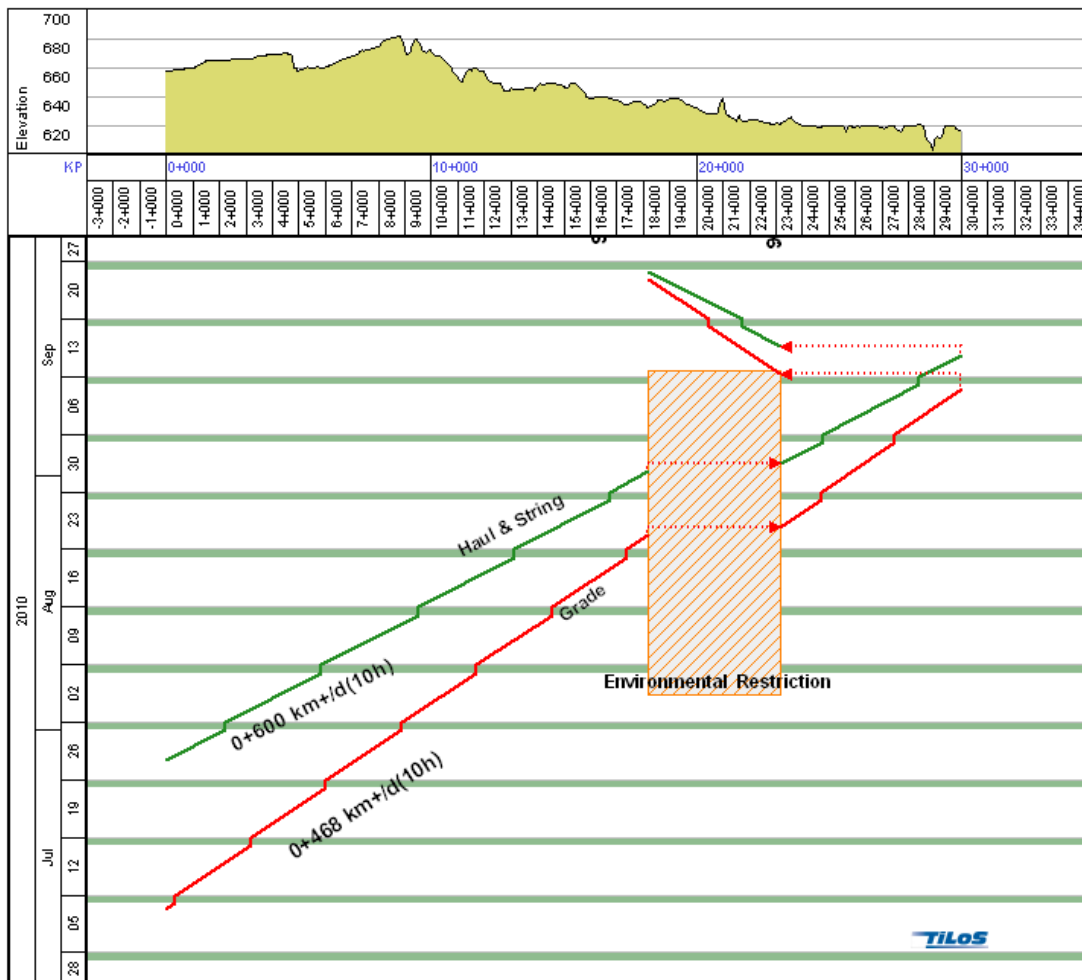


Figure 5 Restricted Access Showing Move Around

CROSSINGS

Once the environmental or land restrictions have been established on your march chart the next step is to identify crossings. Crossing types can include foreign utilities, roads, rail or water and are important features to locate on your march chart. The method of crossing will be dependent on the type of crossing. Water crossings usually require an open cut (if permissible under the environmental guidelines) or will utilize a HDD (Horizontal Directional Drill). Most roads and rail crossings utilize some type of bore method while foreign utilities are exposed using a hydrovac. Each type of crossing can be color coded on the march chart for quick and easy identification.

Figure 6 (below) shows a highway (at KP 1+793) shown in grey and a blue river crossing (KP 29+690) on the march chart.

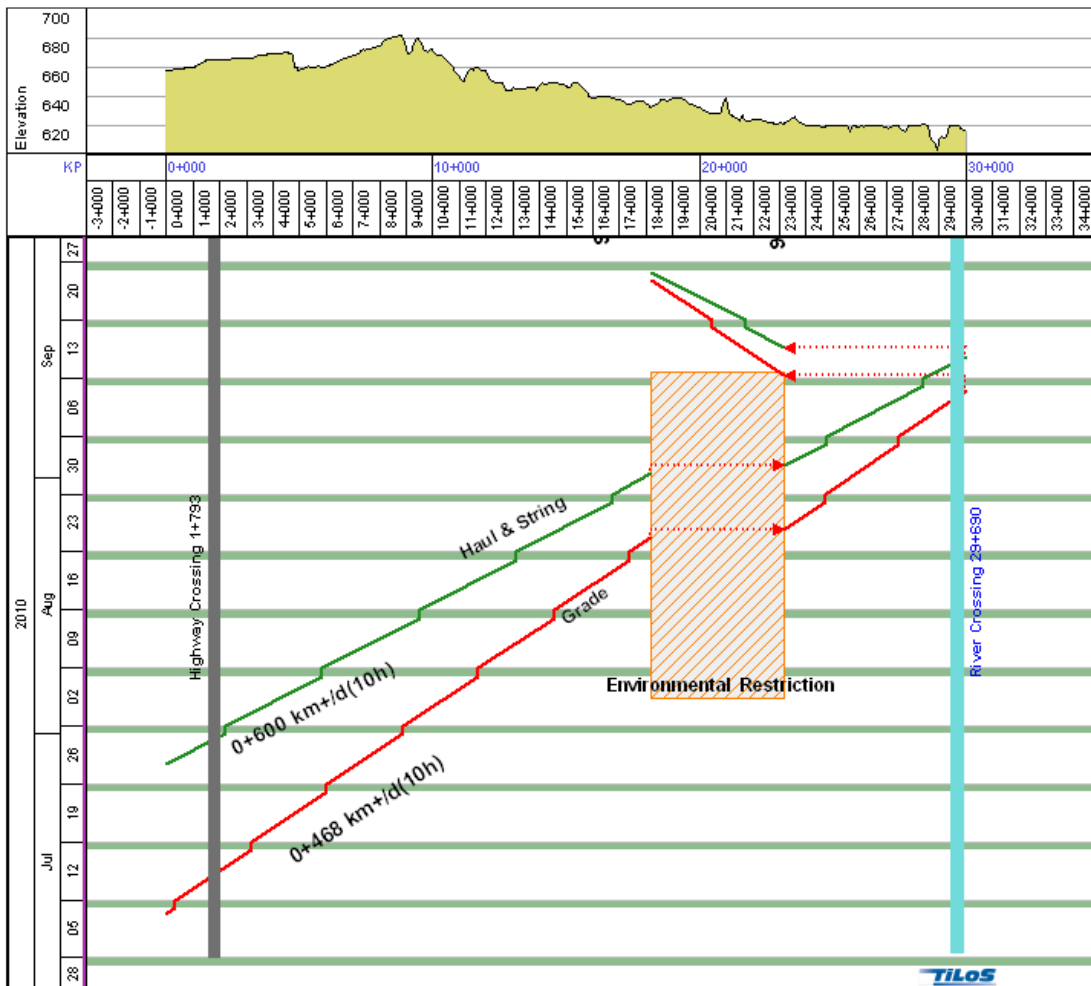


Figure 6 Road and River Crossings

STOCKPILE LOCATIONS AND VALVE SITES

Virtually any information that is important can be inserted into the march chart. The following example (Figure 7) shows the stockpile location (KP 26+102) and the supply zone for this pipe (KP 0+000 to KP 29+655). It is interesting to note that stationary items (such as mainline block valves) can also be shown on a march chart. The two valves shown in Figure 7 are represented by a series of rectangular shapes indicating different stages of installation from civil to mechanical to instrumentation and telemetry.

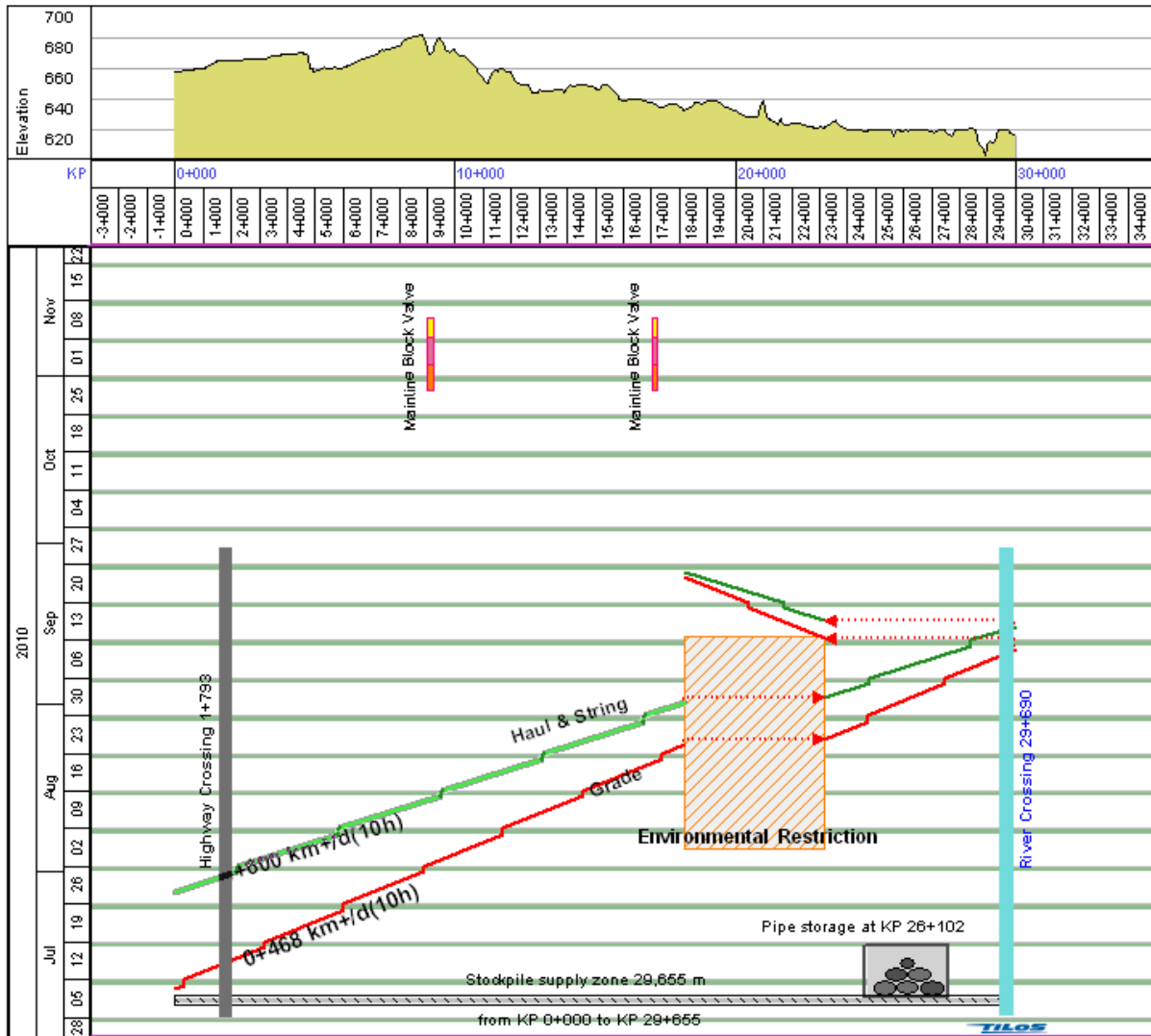


Figure 7 Stockpile Sites and Valve Locations

WEATHER RISK

Risks related to weather events (precipitation amounts, temperatures) are easily evaluated by overlaying meteorological data on the march chart. In the Figure 8 the different shades of blue represent average monthly rainfall amounts. The heaviest amounts of rain occur in the lower right of the march chart (represented by a darker blue). In this example the planner has avoided working in this area during high rainfall amounts thus reducing the risk of heavy rain impacting construction.

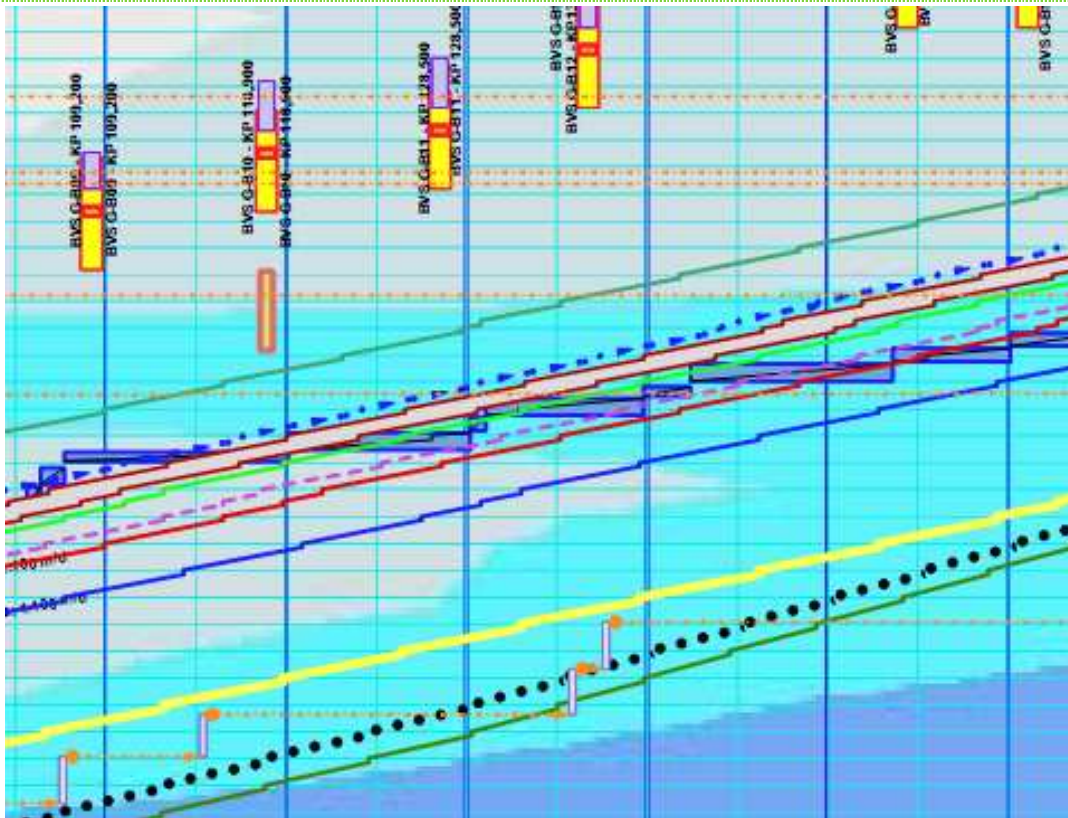


Figure 8 March chart showing monthly average rainfall data.

SPEND PROFILES AND RESOURCE HISTOGRAMS

Spend profiles and resource histograms are simple to create once costs are added to labour, equipment and materials used in the march chart. Figure 9 illustrates an example where the weekly cost per crew and the total cumulative cost is presented in a histogram and table. It is also possible to display the resource histogram per week (or month or day) to determine camp requirements. Spend profiles are a function of time and are displayed parallel to the time axis of the march chart. It is also possible to create a spend profile parallel to the distance axis to show the cost per section of the pipeline. Any changes to the march chart (i.e. crew moves) would automatically create a change to the spend profile.

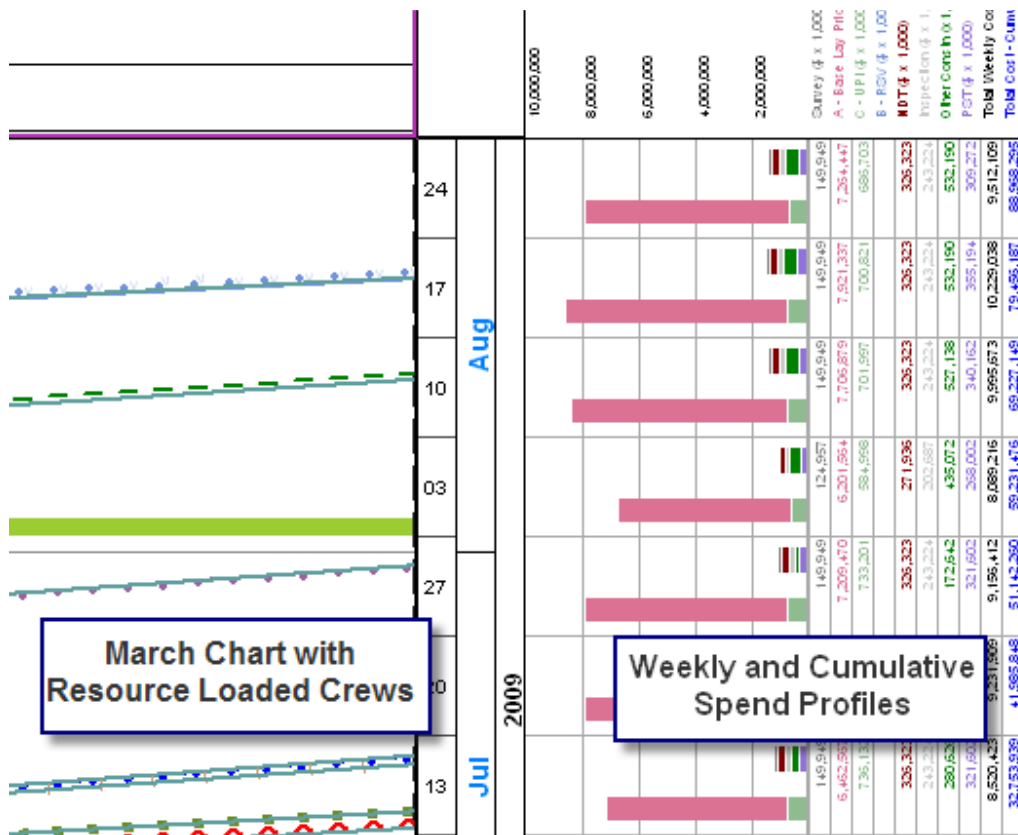


Figure 9 Weekly Spend Profile (per crew with weekly and cumulative totals)

APPLYING WORK AND SPEED PROFILES TO CREWS

Most estimates, schedules and march charts assume a consistent productivity (or work) rate for each pipeline crew along the ROW. This productivity factor is then applied for the entire length of the spread to determine the duration of each crew. Applying a constant productivity rate for a crew doesn't account for changes in profile, soil, terrain (muskeg versus mineral soil conditions) or vegetation type.

For example, a logging crew that has a productivity rate of 2000 m/day would require 15 days to complete a 30 km ROW. While this provides a rough estimate it doesn't account for productivity rates based on changes in vegetation types or whether there is any logging required in certain areas (for example an old burn area that doesn't have any salvageable timber).

The following examples (Figure 10 and Figure 11) illustrate the difference when a vegetation classification system is used to define the productivity rates for a logging and clearing crew in a Northern pipeline spread. In this example the vegetation data and productivity rates for both crews in a particular location were imported directly into the march chart from an Excel data file supplied by a survey.

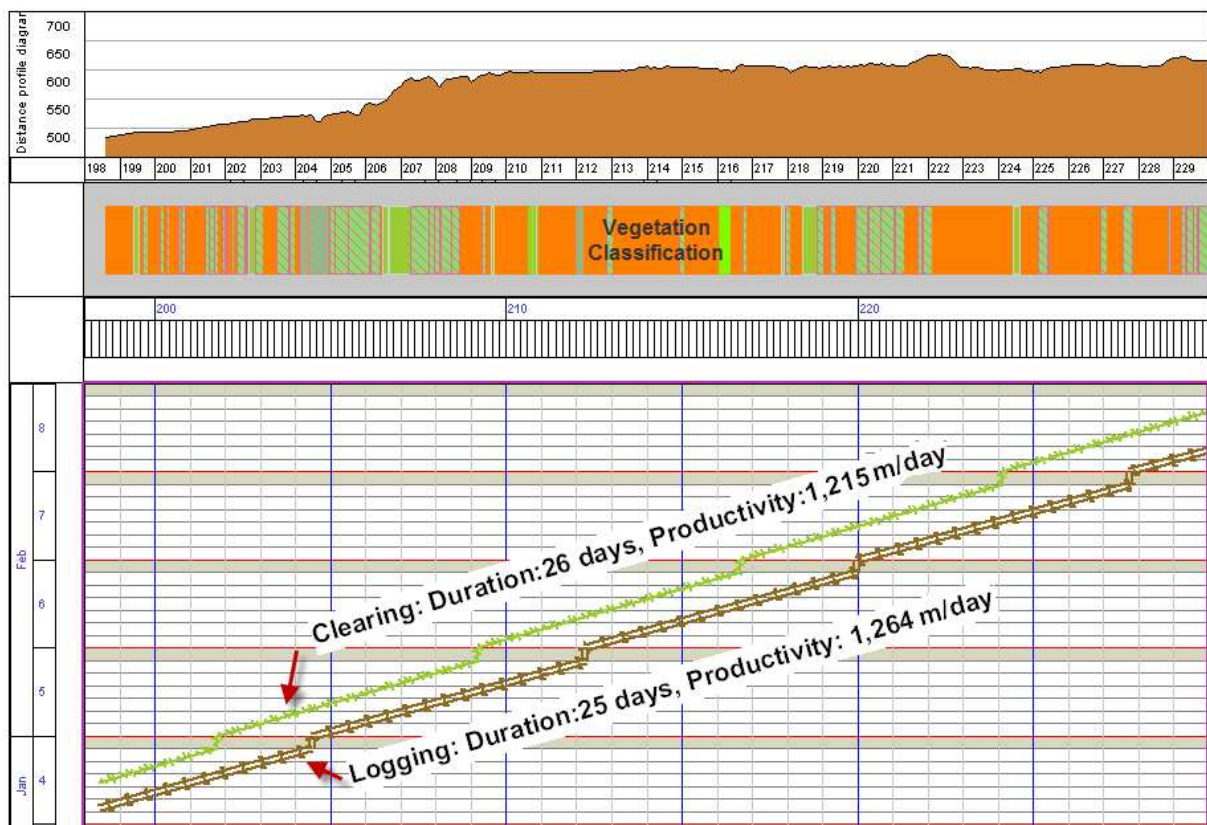


Figure 10 Logging and Clearing Crews with constant productivity

In Figure 10 we can see that the logging and clearing crews have very similar productivity rates and a duration of 25 and 26 days respectively for the logging and clearing crews.

The vegetation index in this example defines the amount of work (area in ha) and work rate for each vegetation type along the ROW. Once this data is known and available in a spreadsheet format, it is easy to apply this index to each crew as shown in Figure 11 below. The first noticeable change is that the crews are not consistently progressing along the ROW. Each crew line now reflects a different productivity rate with each change in vegetation type. More importantly we can see that the duration for each crew has changed significantly. Logging has decreased from 25 days to 16 days while the duration for Clearing has increased from 26 days to 40 days!

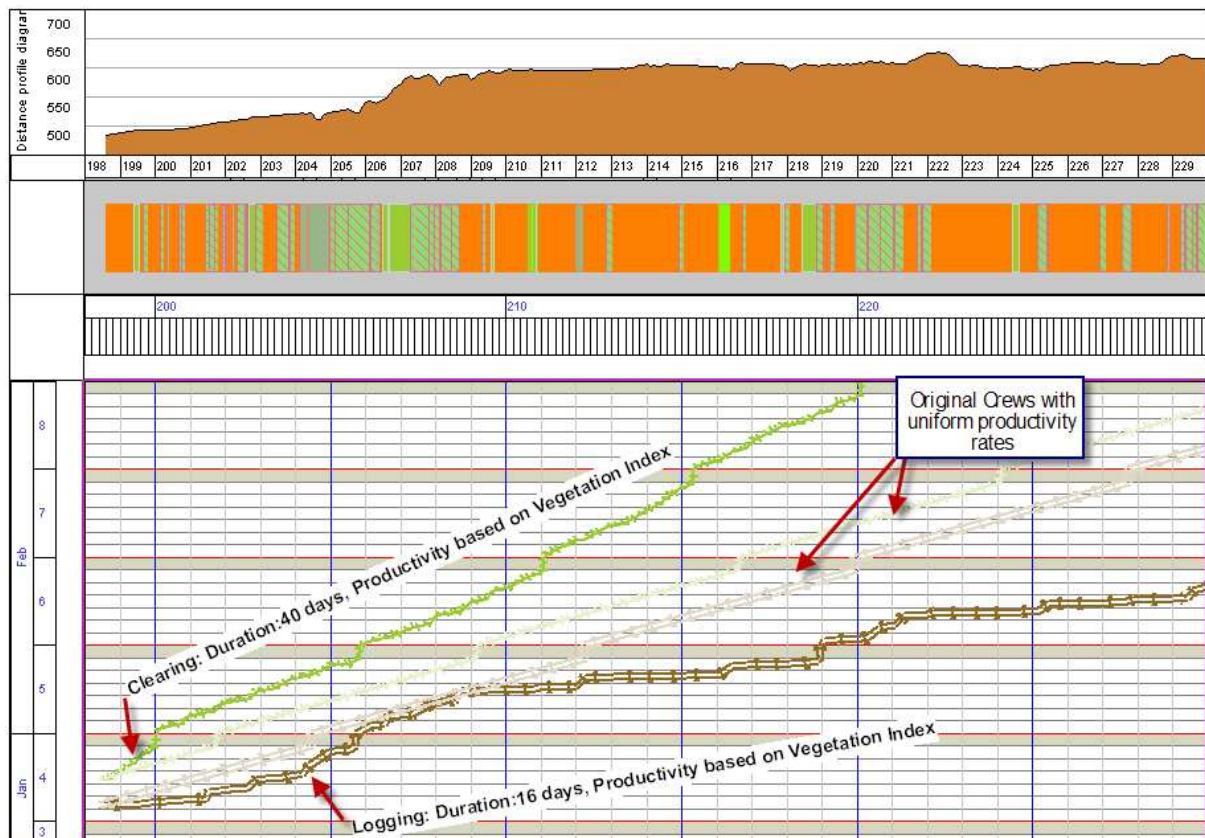


Figure 11 Logging and Clearing optimized by vegetation index

This approach could easily be used in any other geographic location where a known variable impacts the work rate of crews along a ROW. The ability to define productivity in terms of the ROW conditions will enable you to create a more accurate project plan and spend profile when compared to simply applying a uniform rate to each crew.

Applying a speed profile to a crew, based on known changes in productivity, creates a more accurate picture of how the crew is moving along the pipeline ROW (Figure 12).

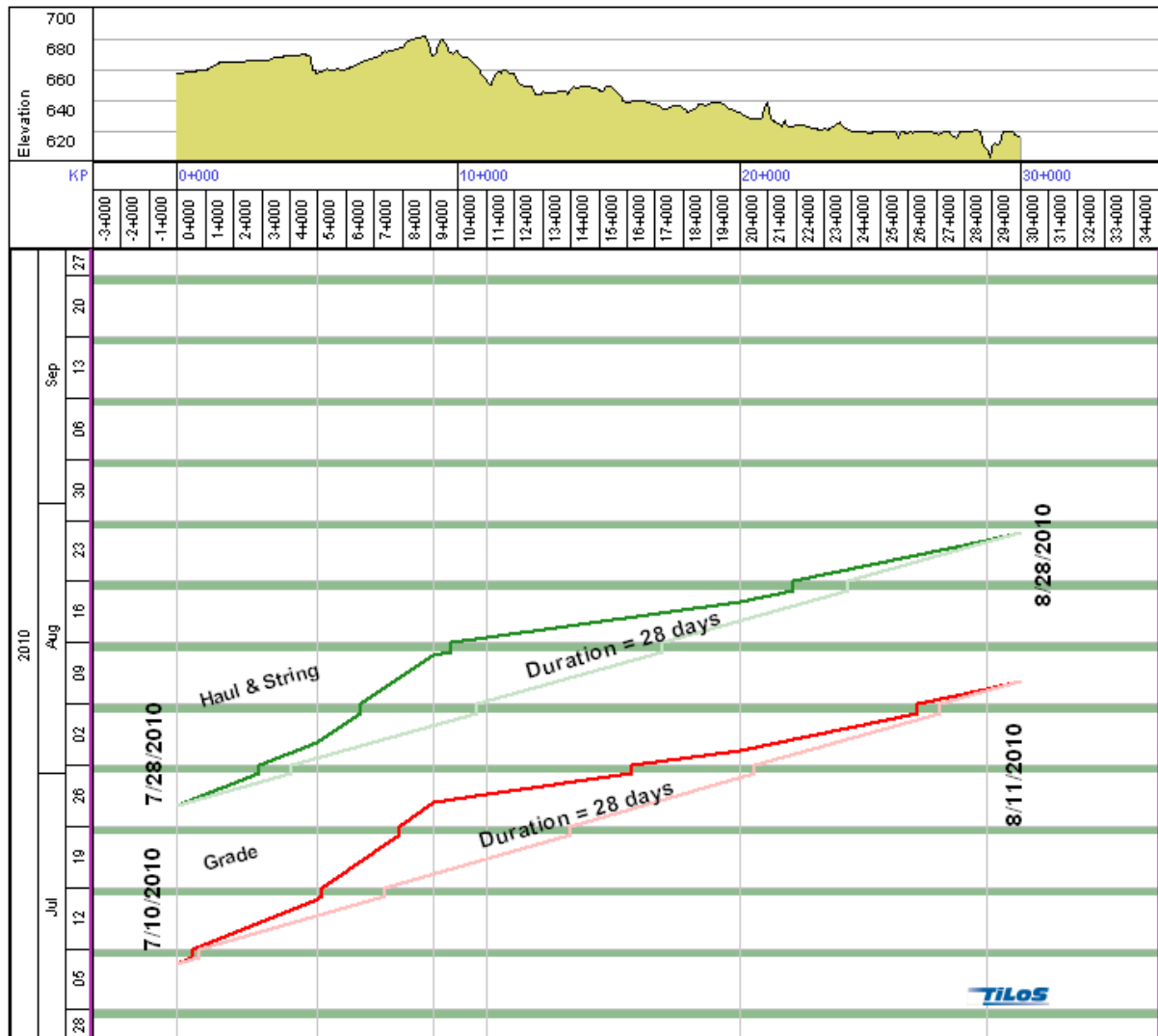


Figure 12 Crew Speed profile

PROGRESSING MARCH CHARTS

Progressing crews on a march chart requires the start KP, end KP and the date range for each progress period (based on the inspector field reports) is applied. The exception to linear meters would be counting the number of welds (usually back end welds) or the number of UPI items (such as bag weights).

Figure 13 (below) shows progress for both the grade and the haul & string crews. Progressing is as simple as selecting a crew by clicking on it, right click and select enter progress. Enter the start

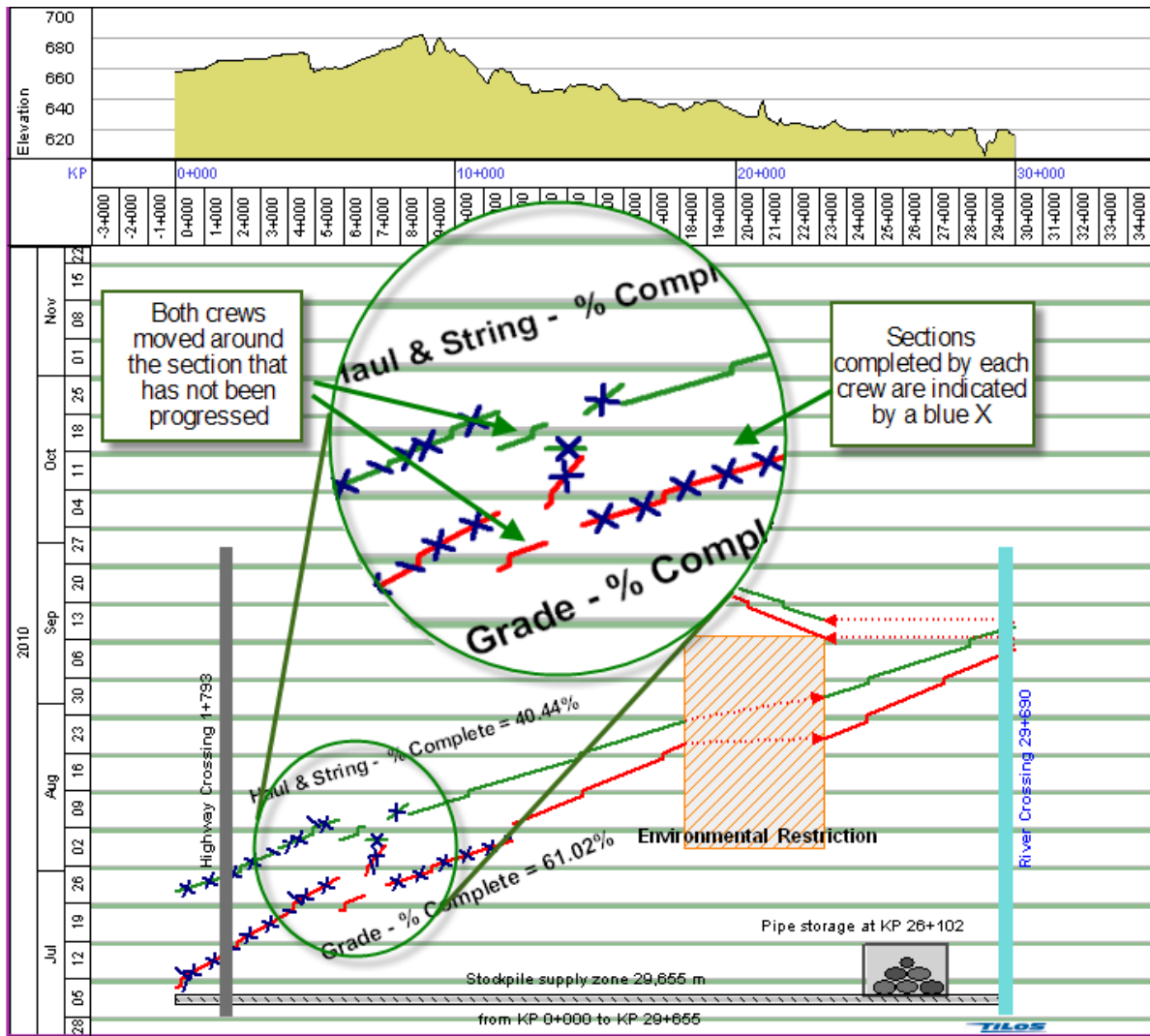


Figure 13 Progressing Crews in March Charts

and end date for the progress period and the start and end KP. The march chart software calculates the physical percent complete based on the amount of work completed divided by the total length of the pipeline. In this example grading is 61.02% and haul & stringing is 40.44% complete. It should be noted that this progress is for the segment that starts at KP 0+000 and ends at restricted access area, it doesn't include the other two segments for each of these crews.

PROGRESS BAR CHARTS

Progress can also be indicated in a bar chart format where each the progress of each crew is represented by a shaded bar chart. As progress is applied to a crew the bar chart view is automatically updated to reflect this progress. In Figure 14 the direction of build is from right (KP 162+000) to the left (KP112+000). In this example the clearing, pioneering and grade crews have completed the entire length of the spread. Haul & String are between 40% and 50% complete. The automatic welding crew has just started.

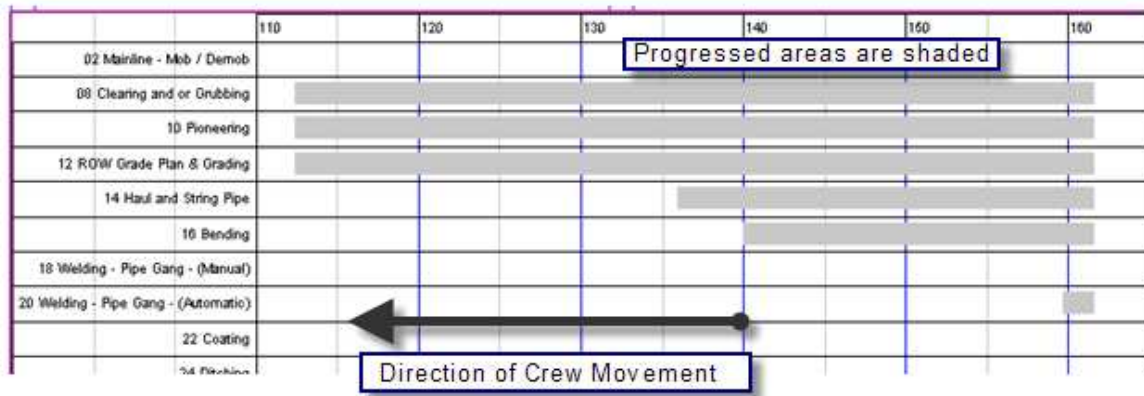


Figure 14 Crew Progress Bar Chart

CONCLUSION

The goal of this guide was to provide a comparison of traditional scheduling tools to march charts which are better suited for linear construction projects such as a pipeline. This overview of march charts went from explaining and drawing simple lines on the march chart, to adding constructability issues (environmental restrictions) and risk (weather). Other risks can just as easily be added to the march chart to develop a clearer picture of the pipeline job. Creating spend profiles is simply a matter of applying costs to each crew.

As described, it is fairly easy to apply speed and work profiles to crews to connect the productivity rates to soil, timber or any other factor that will have an impact. Progressing during project execution is dependent on the addition of crew inspector report data. Typically the start and end KP for each crew is recorded daily. UPI items and welding may be tracked as the number installed or completed each day.

March charts connect the schedule to the geography and risks of a project in a manner that is not at all possible using non-linear methods. Hopefully this guide has helped you understand the basics of march charts and the opportunities that are possible.

Special thanks to the author, Lorne Duncan, for his permission to distribute this document. Lorne has substantial experience in pipeline construction and applying march chart technology to the successful planning and execution of pipelines. He can be contacted at lorne.duncan@integrated-project-services.com